METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR NOVEMBER, 1954 Vol. 50 No. 301

PUBLISHED MONTHLY BY
The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.
Telephone: BLAckfriars 2084

London Office:
50, Temple Chambers,
Temple Avenue, E.C.4.
CENtral 8914

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Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS
Subscription Rates throughout the World—24/- per annum, Post free.

ADVERTISING
Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX

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Management Training

IF it be true that managers are born, not made, then the birth rate for this particular species of *homo sapiens* is too low in this country. At least, such a conclusion can be drawn from the reports issued by the various productivity teams that have visited the United States to study particular branches of American industry, for among features put forward to explain the apparently higher industrial productivity of the American worker, better management is included along with the greater amount of power available to the worker, a more enlightened outlook on the part of both organised labour and the individual worker, and a number of other factors. It would, of course, be wrong to accept these references as sweeping generalisations, which the teams who had given much thought to the matter never intended them to be. In fact, many reports emphasise that, whilst the average productivity of U.S. firms is probably higher than the general standard over here, the best in British industry is as good as, and maybe better than, the American best; this is true of management no less than of other factors, but so long as there is room for improvement, every effort should be made to achieve it.

So many of the attributes which go to the making of a good manager are of a personal nature that there is at least an element of truth in our opening premise. It is also true, however, that those possessing the necessary qualities still do not automatically become first-class managers without training. On the other hand, even those who basically fall short of the ideal, and who are never likely to become captains of industry, can derive great benefit from appropriate training and, as a result, discharge their supervisory duties the more effectively. In the past considerable attention has been paid to the training of craftsmen, technicians and office workers by the provision of suitable classes by the local education authorities and, in the case of the larger firms, by the provision of training facilities within the works. The local authorities' courses were at one time mainly organised as evening classes, and those who successfully completed a course lasting some six years, studying and doing homework in the evening after a long day's work, could certainly claim to have got there the hard way. There is an increasing tendency now for firms to allow their younger employees to attend such courses on one day in the week instead of three evenings, a system known in some parts of the country as "day release." In recent years the importance of management training has been increasingly appreciated, and various types of course have been designed. Some of the residential type involve the trainee's absence from his usual work for a number of weeks, and whilst such courses have their advantages, they may be impracticable in the circumstances prevailing in many firms. One large industrial organisation has now adopted a "day release" course for junior managers, and the results of the first year's working are regarded as being most encouraging.

An account of the T.I. Management Development Course appeared in the October issue of *Journal of the British Association for Commercial and Industrial Education* in the form of an article by Brigadier F. I. de la P. Garforth, deputy director of training and welfare to Tube Investments, Ltd. The objects of the course were set out on the following lines. "The chief aim should be to make members of the group (i.e., the trainees) better at effectively applying the knowledge and experience they already have rather than to pump in a mass of abstract theory and factual information. The course should broaden their concept of the range and depth of management responsibilities, and of how these fit into the general economic and social situation, and should make them more aware of modern trends in management and of the techniques and procedures which are available. Above all, it should make them better at putting across their own ideas and points of view, and at understanding those of other people." The course was organised to occupy a session of three terms, each of ten Thursdays in consecutive weeks, with breaks over Christmas and Easter. Apart from the proceedings each Thursday, the syllabus included private work involving preparation of talks, reading appropriate books, and a weekly study of the *Listener* and the *Economist*.

One disadvantage of the "day release" course as compared with the residential course is the loss of the exchange of ideas which takes place in the evenings at the latter, coupled with the fact that a residential course takes place away from the worries of the job. On the other hand the day a week course has a number of advantages, and even having to get through five days' work or four plus overtime may not be without its benefits: in particular, some of those who took the course said they were forced to organise their work better and to delegate more effectively.

The break of a week between course days makes it possible to include private reading and preparation in the programme: this is extremely valuable in certain subjects, and enables a number of purely informational lectures to be cut out of the syllabus, providing time for items with a more practical and personal impact. There is, too, a likelihood that, where the course is interwoven with the daily working life of the trainee the teaching will be more readily assimilated into his everyday thinking, and lead to more durable benefits. Other advantages of a course spread over several months include elasticity in planning and adaptability to the development of the trainees and to suggestions put forward by them.

From the company's point of view, it will usually be easier to spare a manager for one day a week for seven or eight months than to allow him to spend four or five consecutive weeks on a residential course. Furthermore, Brigadier Garforth suggests, a management development course of this type—perhaps not so long and elaborate, and possibly on a half-day basis—is, with a little outside help, within the resources of single companies of comparatively modest size.

Meeting Diary

17th and 18th November

Iron and Steel Institute. Autumn Meeting. 4, Grosvenor Gardens, London, S.W.1. 10.15 a.m. and 2.30 p.m. Wednesday; 10 a.m. and 2.30 p.m. Thursday.

18th November

Liverpool Metallurgical Society. "The Fracture of Metals," by C. E. Phillips. Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool. 7 p.m.

North East Metallurgical Society. "Aluminium and its Alloys as Engineering Materials," by E. Elliott. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

19th November

West of Scotland Iron and Steel Institute. "Direct-Reading Spectrographic Analysis of Ferrous Metals, with Special Reference to the Use of the Quantometer," by A. Argyle. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

23rd November

Sheffield Metallurgical Association. "Chemical Analysis: Some Physical-Chemical Considerations" by C. E. A. Shanahan. B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

24th November

Institute of Metals, Sheffield Local Section. "High-Temperature Water-Cooling of Open-Hearth Furnaces by Means of Steam-Producing Elements," by F. J. Feltoe and P. M. Moreton. "The Cooling of Large Rolling Mill Drives," by P. M. Moreton. Joint Meeting with the Yorkshire Branch of the Institution of Mechanical Engineers and the Sheffield Society of Engineers and Metallurgists, Mappin Hall, Sheffield. 6.30 p.m.

Manchester Literary & Philosophical Society (Chemical Section). "Atomic Energy." Portico Library, 57, Mosley Street, Manchester. 6 p.m.

Manchester Metallurgical Society. "Some Experiences in Industrial Research," by Dr. B. P. Dudding. Lecture Room, Central Library, Manchester. 6.30 p.m.

25th November

Institute of Metals, Birmingham Local Section. "The Working of Metals," by J. G. Wistreich. James Watt Memorial Institute, Great Charles Street, Birmingham. 6.30 p.m.

Royal Statistical Society Industrial Applications Section (Sheffield Group). "Some Examples of the Use of Statistical Methods in Steel Works," by K. C. Padley. Cavendish Room, Grand Hotel, Sheffield. 7 p.m.

2'th and 26th November

Institute of Metals. General Meeting for the discussion of scientific papers. 4, Grosvenor Gardens, London, S.W.1. 2.30 p.m. Thursday; 10 a.m. and 2.30 p.m. Friday.

26th November

Institution of Mechanical Engineers. "Dynamic Stresses in Electric Overhead Travelling Cranes Due to the Hoisting and Lowering of Loads," by E. Lightfoot and B. L. Clarkson. 1, Birdcage Walk, Westminster, London, S.W.1. 5.30 p.m.

Manchester Association of Engineers. "Submarine Telegraph and Telephone Cables," by F. Mattingley. The Engineers' Club, Albert Square, Manchester. 6.45 p.m.

29th November

Incorporated Plant Engineers. West and East Yorkshire Branch. "Fuel injection equipment for High Speed Oil Engines," by W. H. Simpson. Leeds University, 7.30 p.m.

Institution of Structural Engineers. "The Design Features and Collapse Investigations of the Tacoma Narrows Bridge," with film, by S. M. Cooper. Reynolds Hall, College of Technology, Manchester. 6.30 p.m.

30th November

Sheffield Metallurgical Association. "Open Hearth Furnaces. (iii) Acid Roofs." B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

1st December

Institute of Metal Finishing, Scottish Branch. "Practical Bright Nickel Plating," by T. E. Such. 39, Elmbank Crescent, Glasgow. 7 p.m.

Institute of Welding. "Welding in the Manufacture of Lifting Tackle," by W. G. Biggart. Reynolds Hall, College of Technology, Manchester. 7.15 p.m.

1st and 2nd December

Iron and Steel Institute and Institute of Metals. Symposium on Powder Metallurgy. The Hoare Memorial Hall, Church House, Westminster, London, S.W.1. 9.30 a.m., and 2.15 p.m. Wednesday; and 9.30 a.m. and 2 p.m. Thursday.

2nd December

Institute of Metal Finishing, North-West Branch. Film on "Spray Painting," followed by a talk on "Recent Developments in Spray Painting," by R. A. W. Ottley. Engineers' Club, Albert Square, Manchester. 7.30 p.m.

Institute of Metals. Joint Meeting with the Chemical Engineering Group of the Society of Chemical Industry. "Thermochemistry of Alloys," by Dr. A. R. Harding. University Chemical Department, Woodland Road, Bristol. 6.30 p.m.

3rd December

Institution of Mechanical Engineers. "The Roll-setting Method of Automatic Control of Gauge in Hot and Cold Rolling Mills," by R. B. Sims and K. H. Slack. 1, Birdcage Walk, Westminster, London, S.W.1. 5.30 p.m.

6th December

Institute of British Foundrymen (Sheffield and District Branch). Discussion: "Methods of Making a Typical Casting in Cast Iron." Discussion led by F. Greaves, J. Richardson and D. Sorsby. College of Technology, Pond Street, Sheffield. 7.15 p.m.

Sheffield Society of Engineers and Metallurgists. Annual General Meeting. "The Park Gate 11-in. Continuous Bar Mill," by W. Udall. Joint Meeting with the Engineers' Group of the Iron and Steel Institute, and the Institute of Metals, (Sheffield Local Section). University Buildings, St. George's Square, Sheffield. 7.30 p.m.

7th December

Incorporated Plant Engineers. "Heat Treatment of Steel," by C. Haywood. Royal Society of Arts, John Adam Street, Adelphi, Strand, London. 7 p.m.

Institute of Metal Finishing, Midland Branch. "The Protective Qualities of Phosphate Coatings on Steel," by Dr. S. G. Clarke. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 6.30 p.m.

Institute of Metals, Oxford Local Section. Junior Members' Evening. Discussion on "Alloy Constitution; Practical Techniques." (1) "Laboratory Furnaces and Temperature Control," opened by A. T. Thomas (2) "High-Temperature Thermal Analysis," opened by Miss D. Murray. (3) "Design of Arc Furnaces," opened by A. Hellawell. Ballroom of the Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Sheffield Metallurgical Association. "The Determination of Nitrogen in Steel," by Dr. J. D. Hobson. B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

8th December

East Midlands Metallurgical Society. "Acid Burdening of Blast Furnaces," by J. Colvin. Nottingham & District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

Manchester Metallurgical Society. General Discussion on Mechanical Testing. Lecture Room, Central Library, Manchester. 6.30 p.m.

10th December

Institution of Mechanical Engineers. "Cylindrical Pressure Vessels: Stress Systems in Plain Cylindrical Shells and in Plain and Pierced Drumheads," by Dr. W. B. Carlson and J. D. McKean. 1, Birdcage Walk, Westminster, London, S.W.1. 5.30 p.m.

13th December

Institute of Metal Finishing, London Branch. "Recent Developments in Chromium Plating," by H. Silman. Northampton Polytechnic, St. John Street, London, E.C.1. 6.15 p.m.

Institute of Metals, Scottish Local Section. "Casting, Fabrication and Testing." 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

Institution of Engineering Inspection, Wolverhampton Branch. "The Manufacture, Inspection and Testing of Springs," by C. Harris. Compton Grange, Compton Road, Wolverhampton. 7.30 p.m.

Continued on page 224

Diffusion between Electrodeposited Copper and Zinc Alloy Die Castings

By C. W. Roberts, B.Sc., A.I.M.

The Imperial Smelting Corporation, Ltd.

The blistering of chromium-plated zinc alloy die castings has been attributed to diffusion between the copper undercoat and the zinc alloy. This paper presents the results of an investigation into the effects, on the extent to which diffusion occurs, of such factors as surface condition, cleaning procedure, temperature to which plated castings are subsequently exposed and time of exposure to such temperatures.

A SUBSTANTIAL proportion of the zinc alloy die castings produced are electroplated prior to going into service, the purpose of the electroplate being partly to protect the casting against corrosion but mainly to improve appearance. The normal procedure is to deposit a prescribed thickness of copper on to the zinc alloy surface after suitable pretreatment—which includes polishing, degreasing, cathodic cleaning and pickling—then to plate a coating of nickel on to the copper, and to finish with a flash of chromium. The defect most commonly encountered in castings thus finished is blistering of the plating; the blisters often develop during plating, or soon after plating has been completed, but sometimes only after the casting has been in service for some considerable time.

The cause of blistering has been investigated by several workers but their conclusions, while broadly in agreement, differ in certain details.

Castell[1] investigated the failure of the plating on zinc alloy die castings during outdoor exposure, and reported that diffusion occurred between the copper deposit and the base metal. He did not, however, find any correlation between the occurrence of diffusion and the rate of deterioration of the electroplate. He reported that the rate of diffusion at high temperatures (105–232° C.) was rapid, but was very slow at room temperatures, rate of diffusion being expressed as reduction in thickness of copper deposit with time.

Anderson and Reinhard[2] concluded that the formation by diffusion of a layer of a brittle copper-zinc alloy was the main cause of blistering, this alloy layer being too weak mechanically to withstand any pressure tending to lift the plate from the surface of the casting. They laid particular emphasis on the effect of cleaning time (cathodic cleaning in a solution of trisodium phosphate or similar alkaline reagent) on the rate of diffusion between the copper subsequently deposited and the zinc alloy, long immersion in such a solution increasing the rate of diffusion considerably. They noted also that the rate of diffusion was more rapid when the surface of the casting was not polished prior to plating.

The effect of variations in pretreatment on the incidence of blistering of electrodeposits was investigated by Oplinger[3], who also concluded that diffusion was a direct cause of blistering. He recommended the use, for cathodic cleaning and acid pickling, of dilute solutions and minimum time of immersion in such solutions, as measures calculated to reduce the possibility of diffusion occurring between the copper deposit and the zinc alloy. Figures are included in the paper illustrating the effect of immersion time in, and strength of, the pretreatment solutions on the thickness of the alloy layer formed by diffusion at temperatures up to 163° C. for periods of time up to 132 hours.

Experimental Technique

Published work on the subject has been concerned in the main with the effect of variations in pretreatment on the incidence of diffusion. It appeared desirable, therefore, to standardise the pretreatment, and to investigate in greater detail the effect of temperature and time at temperature on the progress of diffusion between electrodeposited copper and the zinc alloy.

The published information has indicated that the rate at which the copper deposit and the zinc alloy inter-diffuse is influenced to a greater or lesser extent by the following variables :—

(1) State of surface of casting—polished or unpolished.
(2) Duration of cathodic cleaning operation and strength of cleaning solution.
(3) Temperatures to which plated castings are subsequently exposed.
(4) Period over which castings are exposed at these temperatures.

In the normal production schedule, zinc alloy die castings are first polished and then cleaned cathodically, the recommended cleaning operation involving immersion for not more than 30 seconds in a reagent that is essentially a 3·7% solution of trisodium phosphate in water.

Plated zinc alloy die castings are not normally exposed to very high temperatures, but lacquers or enamels are sometimes applied afterwards and such coatings may require stoving at a temperature up to 150° C. Somewhat rarely, plated die castings are subjected to temperatures in the order of 200° C. for short periods of time. For example, die castings are sometimes copper plated to facilitate soldering, and in such an operation a local temperature appreciably above 200° C. may well be attained. Plated die castings fitted to certain industrial installations may be exposed to moderately high temperatures for long periods of time, as might such castings used outdoors in the tropics.

TABLE I.—DETAILS OF ANNEALING TREATMENTS GIVEN TO TEST BARS.

	Annealing Temperature					
	250° C.	220° C.	190° C.	160° C.	120° C.	100° C.
	Minutes				Hours	
Time at Temperature	0 3 7 15 30 60	0 3 7 15 30 60	0 5 10 20 45 90	5 12 24 40 90 180	24 48 72 96 168 —	1 2 4 8 16 32 Weeks 1 2 5 9

To cover all probable contingencies the following ranges of variables were chosen for the present experiments.

Temperature	100 to 250° C.
Time at temperature	3 minutes to 9 weeks.
Duration of cathodic cleaning operation	30 seconds or 5 minutes.
State of cast surface	Polished or unpolished.

Test pieces of Mazak 3 (B.S.1004 Alloy A) in the form of pressure die cast bars, cross section ¼ in. square, length 6 in., were selected, divided into two groups, designated A and B respectively, and plated under the following conditions.

Group A

Two sides were polished and the remaining two were left unpolished. Test pieces were degreased, then cleaned cathodically in a 3·7% solution of trisodium phosphate for 30 seconds. After washing in water the test pieces were given a brief dilute sulphuric acid dip and then electroplated by conventional methods to obtain the following thickness of plate.

Copper	0·0002–0·0003 in.
Nickel	0·0004–0·0006 in.
Chromium	0·000015 in.

Group B

As Group A, except that the duration of the cathodic cleaning operation was extended to 5 minutes.

The bars were cut into 1 in. lengths which were annealed for various periods of time at selected temperatures, as shown in Table I.

Complete cross sections were then cut from each bar; they were prepared for metallographic examination by conventional methods and examined at suitably high magnification. The thickness of the alloy layer formed by diffusion during heat treatment and the thickness of the remaining copper plate were measured and the results obtained are shown in Tables II–VII.

TABLE II.—EXTENT OF DIFFUSION AFTER ANNEALING AT 250° C.

Identity*	Duration of Anneal (min.)	Thickness of Copper Plate (in.)	Thickness of Alloy Layer (in.)
A1	0	0·00025	0·0000
A1	3	0·00020	0·00004
A1	7	0·00013	0·0002
A1	15	0·00010	0·0003
A1	30	0·00003	0·0005
A1	60	0·00003	0·0008
B1	0	0·00026	Slight indication
B1	3	0·00020	0·00015
B1	7	0·00020	0·00020
B1	15	Plate and alloy layer broken away	
B1	30	0·0002	0·0004
B1	60	Plate and alloy layer broken away	

* Series A cleaned cathodically 30 seconds.
Series B cleaned cathodically 5 minutes.

Experimental Evidence

The photomicrographs shown in Figs. 1–6 (× 500) were taken to illustrate the appearance of the cast surface/copper plate interface after the various conditions of heat treatment.

Fig. 1 shows the "as-plated" polished surface of a specimen cleaned cathodically for 30 seconds, the copper plate being 0·0002 in. in thickness and the nickel 0·0004 in.

Fig. 2 illustrates the effect of annealing for 32 hours at 100° C. on a plated surface which had not been polished, but which had been cleaned cathodically for 5 minutes. The thickness of the alloy layer in this specimen was, on average, 0·00013 in., whereas on the unpolished surface of the specimen that was cleaned cathodically for 30 seconds and heat treated in a similar manner the thickness of the alloy layer was only 0·00008 in.

Figs. 3 and 4 illustrate the effect of surface state and duration of the cathodic cleaning operation on specimens that were annealed at 120° C. for 24 hours. At the polished surface of the specimen that had been cleaned cathodically for 30 seconds, the alloy phase was present as disconnected globules which rarely exceeded 0·00003 in. in thickness (Fig. 3), whereas a continuous alloy layer of average thickness 0·00017 in. was observed at the unpolished surface of the corresponding specimen

TABLE III.—EXTENT OF DIFFUSION AFTER ANNEALING AT 220° C.

Identity*	Duration of Anneal (min.)	Thickness of Copper Plate (in.)	Thickness of Alloy Layer (in.)
A2	0	0·00020	0·000
A2	3	0·00020	Very slight
A2	7	0·00026	0·0001
A2	15	0·00013	0·0002
A2	30	0·00013	0·00026
A2	60	0·00013	0·00050
B2	0	0·00026	0·00008
B2	3	0·00020	0·00013
B2	7	0·00020	0·00020
B2	15	0·00026	0·00026
B2	30	0·00020	0·00026
B2	60	Plate and alloy broken away	

* Series A cleaned cathodically 30 seconds.
Series B cleaned cathodically 5 minutes.

TABLE IV.—EXTENT OF DIFFUSION AFTER ANNEALING AT 190° C.

Identity*	Duration of Anneal (min.)	Thickness of Copper Plate (in.)	Thickness of Alloy Layer (in.)
A3 P	0	0·00020	Nil
U		0·00026	Nil
A3 P	5	0·00026	Very slight
U		0·00026	Very slight
A3 P	10	0·00020	Very slight
U		0·00026	Very slight
A3 P	20	0·00020	0·00004
U		0·00020	0·00006
A3 P	45	0·00013	0·00013
U		0·00013	0·00026
A3 P	90	0·00013	0·00020
U		0·00013	0·00020
B3 P	0	0·00026	Nil
U		0·00026	Very slight
B3 P	5	0·00026	0·00004
U		0·00026	0·00010
B3 P	10	0·00026	0·00004
U		0·00030	0·00008
B3 P	20	0·00026	0·00013
U		0·00026	0·00020
B3 P	45	0·00026	0·00015
U		0·00026	0·00015
B3 P	90	0·00018	0·00026
U		0·00020	0·00035

* Series A cleaned cathodically 30 seconds.
Series B cleaned cathodically 5 minutes.
P = plated on polished surface.
U = plated on unpolished surface.

TABLE V.—EXTENT OF DIFFUSION AFTER ANNEALING AT 160° C.

Identity*	Duration of Anneal (min.)	Thickness of Copper Plate (in.)	Thickness of Alloy Layer (in.)
A4 P	5	0·00026	Nil
U		0·00026	Very thin
A4 P	12	,,	Very thin
U		,,	Very thin
A4 P	24	,,	Very thin
U		,,	0·00006
A4 P	40	,,	0·00004
U		,,	0·00006
A4 P	90	,,	0·00006
U		,,	0·00020
A4 P	180	,,	0·00018
U		,,	0·00018
B4 P	5	0·00026	Very thin
U		0·00026	Very thin
B4 P	12	,,	Very thin
U		,,	0·00005
B4 P	24	,,	Very thin
U		,,	0·00005
B4 P	40	,,	0·00010
U		,,	0·00013
B4 P	90	,,	0·00010
U		,,	0·00020
B4 P	180	,,	0·00018
U		,,	0·00020

* Series A cleaned cathodically 30 seconds.
Series B cleaned cathodically 5 minutes.
P = plated on polished surface.
U = plated on unpolished surface.

that had been cleaned cathodically for 5 minutes (Fig. 4).

The effect of duration of the annealing treatment on the extent of the diffusion is illustrated by Figs. 5 and 6, both being sections through the polished surface of specimens that had been cleaned cathodically for 30 seconds only. After 15 minutes at 250° C. an alloy layer of thickness 0·0003 in. had been formed (Fig. 5), the copper plate having been reduced to a thickness of 0·00010 in. After an hour at this temperature the copper plate was barely visible, and the alloy layer had increased to 0·0008 in. in thickness (Fig. 6).

To show the relationship between annealing temperature and rate of diffusion (as shown by the thickness of the alloy layer), the thickness of the alloy layer produced at the polished surface of the specimens cleaned for 30 seconds, by annealing for one hour at temperatures of 250, 220, 190 and 160° C., was plotted against these temperatures. This plot is shown as curve X in Fig. 7, while the straight line Y is the best trace through the points correlating the thickness of the alloy layer with the corresponding value of the function $(T - 100)^2$ where T is the annealing temperature in ° C.

Fig. 8 illustrates the relationship between annealing time and thickness of alloy layer at the polished surface

TABLE VI.—EXTENT OF DIFFUSION AFTER ANNEALING AT 120° C.

Identity*	Duration of Anneal (hr.)	Thickness of Copper Plate (in.)	Thickness of Alloy Layer (in.)
A6 P	24	0·00026	0·00003
U		0·00026	0·00006
A6 P	48	—	0·00005
U			0·00010
A6 P	72	—	0·00005–0·00010
U			0·00020
A6 P	96	—	0·00010–0·00013
U			0·00022
A6 P	168	—	0·00013–0·00026
U			0·00030
B6 P	24	0·00026	0·00010
U		0·00026	0·00017
B6 P	48	—	0·00020
U		—	0·00025
B6 P	72	—	0·00025
U		—	0·00030
B6 P	96	—	0·00025
U		—	0·00035
B6 P	168	—	0·00032
U		—	0·00045

* Series A cleaned cathodically 30 seconds.
Series B cleaned cathodically 5 minutes.
P = plated on polished surface.
U = plated on unpolished surface.

of the specimens (cleaned cathodically for 30 seconds) which were annealed for various lengths of time at temperatures of 250, 220 and 190° C. These points lie reasonably close to three straight lines A, B and C, respectively. This indicates that the relationship between rate of diffusion and time within the conditions of the experiment is approximately linear.

The degree of blistering of the electroplate that occurred during annealing was noticeably greater under conditions that produced a thick diffusion layer, i.e., 30 minutes or an hour at temperatures above 200° C. or several weeks at about 100° C. Blistering appeared to be more severe with specimens that had been cleaned cathodically for the longer period of time, and, in certain cases, the electrodeposit broke away completely from the surface of such specimens; see, for example, specimen B, at 15 minutes and 60 minutes in Table II, and specimen B at 9 weeks in Table VII.

An example of the nickel plate breaking away from the alloy layer is shown in Fig. 6.

Summary of Results

(1) The thickness of the alloy layer formed when an electro-deposited copper plate diffuses into pressure die cast Mazak increases with increasing temperature and with time at temperature.

TABLE VII.—EXTENT OF DIFFUSION AFTER ANNEALING AT 100° C.

Identity*	Duration of Anneal	Thickness of Copper Plate (in.)	Thickness of Alloy Layer (in.)
A5 P	1 hr.	0·00026	Nil
U			Very slight
A5 P	2 hr.	,,	Slight
U			Slight
A5 P	4 hr.	,,	Slight
U			Slight
A5 P	8 hr.	,,	Slight
U			0·00004
A5 P	16 hr.	,,	Slight
U			0·00004
A5 P	32 hr.	,,	Slight
U			0·00008
A5 P	1 wk.		0·00004
U			0·00013
A5 P	2 wk.		0·00004
U			0·00026
A5 P	5 wk.	0·00004	0·00065
U		0·00004	0·00070
A5 P	9 wk.	Not visible	0·0008
U		Not visible	0·0009

* Series A cleaned cathodically 30 seconds.
Series B cleaned cathodically 5 minutes.

Identity*	Duration of Anneal	Thickness of Copper Plate (in.)	Thickness of Alloy Layer (in.)
B5 P	1 hr.	0·00026	Nil
U		,,	Slight
B5 P	2 hr.	,,	Slight
U		,,	0·00005
B5 P	4 hr.	,,	Slight
U		,,	0·00008
B5 P	8 hr.	—	0·00006
U		—	0·00010
B5 P	16 hr.	—	Approaching 0·00013
U		—	,, 0·00013
B5 P	32 hr.	—	,, 0·00013
U		—	,, 0·00013
B5 P	1 wk.	—	0·00013
U		—	0·00016
B5 P	2 wk.	—	0·00020
U		—	0·00032
B5 P	5 wk.	0·00010	0·00052
U			0·00065
B5 P	9 wk.	Very thin	Plate and alloy layer broken away
U		Very thin	

P = plated on polished surface.
U = plated on unpolished surface.

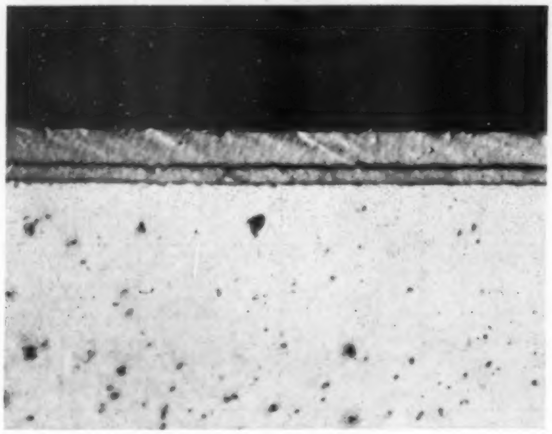

Fig. 1.—Photomicrograph of as-plated polished surface. Unetched. × 500

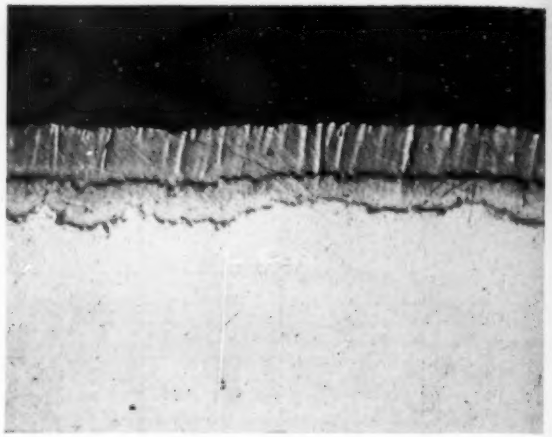

Fig. 2.—Photomicrograph showing diffusion after annealing for 32 hours at 100° C. Plated on an unpolished surface cleaned cathodically for 5 minutes. Unetched. × 500

(2) At the higher temperatures investigated, and over a limited range of time and distance, the approximate relationship between annealing temperature and the thickness of the alloy layer formed by diffusion can be expressed in the form

$$W = C\,(T - 100)^2$$

where W = thickness of alloy layer
T = temperature of annealing in ° C.
and C = constant.

(3) Also at temperatures within the higher range investigated and with the same limitation, the thickness of the alloy layer formed by diffusion at a given temperature is approximately proportional to time at temperature.

(4) The effect of surface state on the rate of diffusion is more noticeable at temperatures below about 200° C. Diffusion is slower when the cast surface is polished, although the effect is more marked when the period of dwell at a particular temperature is short.

(5) The effect of the duration of the cathodic cleaning operation is also more noticeable at temperatures below about 200° C. and at shorter annealing times, diffusion being more rapid with overcleaned specimens. It appears, further, that when overcleaned specimens are annealed at temperatures above about 200° C. for longer periods of time, the bonding at the interfaces cast surface/alloy layer and alloy layer/electroplate is considerably weaker than in specimens that have been cleaned cathodically by immersion for normal periods of time.

Discussion of Results

The zinc alloy used in the present investigation was Mazak 3, the composition of which is zinc, of purity 99·99% with 4% aluminium and 0·04% magnesium. In the zinc-aluminium alloy system, a eutectic occurs at a concentration of 5% aluminium and at temperature 382° C., the components being a zinc-rich solid solution containing 1·15% aluminium and an aluminium-rich solid solution containing 82·8% zinc. The structure of such an alloy on freezing comprises primary crystals of

Fig. 3.—Photomicrograph showing diffusion after annealing for 24 hours at 120° C. Plated on a polished surface cleaned cathodically for 30 seconds. Unetched. × 500

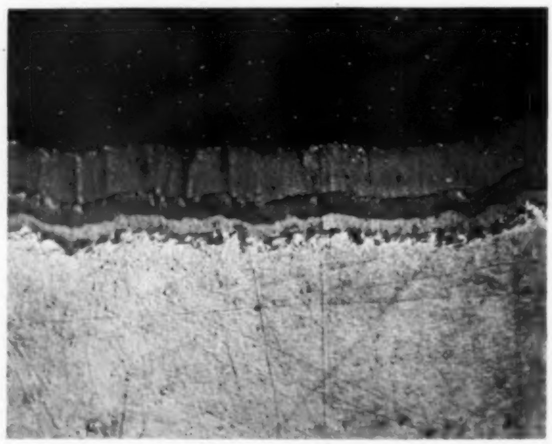

Fig. 4.—Photomicrograph showing diffusion after annealing for 24 hours at 120° C. Plated on an unpolished surface after cleaning cathodically for 5 minutes. Unetched. × 500

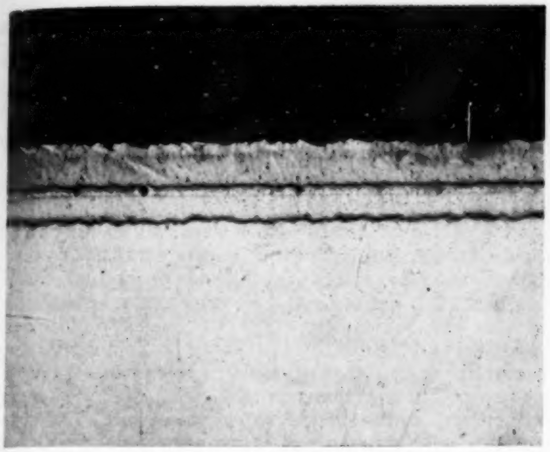

Fig. 5.—Photomicrograph showing diffusion after annealing for 15 minutes at 250° C. Plated on polished surface cleaned cathodically for 30 seconds. Unetched. × 500

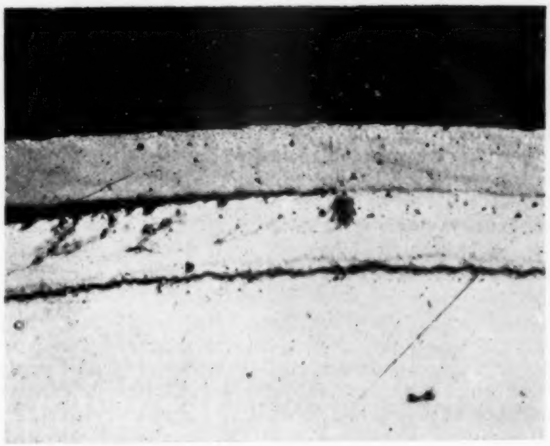

Fig 6.—Photomicrograph showing diffusion after annealing for 1 hour at 250° C. Plated on polished surface cleaned cathodically for 30 seconds.

the zinc-rich phase surrounded by the eutectic. On cooling, the zinc-rich phase precipitates excess aluminium so that the aluminium content of the phase is considerably below the figure quoted above when the alloy cools more or less rapidly. The aluminium-rich phase decomposes by a eutectoid transformation at a temperature of 270° C., but this is not very relevant to the present discussion.

When such an alloy is pressure die cast the metal freezes rapidly, and this results in the formation of a layer of columnar crystals of the zinc-rich phase at the outer surface of the casting, little or no eutectic being present. Diffusion between a copper electrodeposit and pressure die cast zinc alloy may, therefore, be considered for purposes of approximation as diffusion between copper and zinc.

This latter problem has been studied by a number of investigators, and general agreement exists regarding the mechanism of the process. When these two metals interdiffuse, all intermediate phases in the copper-zinc alloy system are formed in addition to the two terminal solid solutions α and η, which are isomorphous with copper and zinc, respectively. The β-phase occupies a very narrow field, the γ-field is much the widest in extent, while the ϵ-phase occupies a zone of intermediate width ; no two-phase fields are formed. The γ- and ϵ-phases are of complex structure and, mechanically, are weak and brittle.

When diffusion occurs between a narrow band of electrodeposited copper and die cast Mazak, it is probable that zinc diffuses rapidly into the copper to form the α-phase, and the copper more slowly into the zinc to

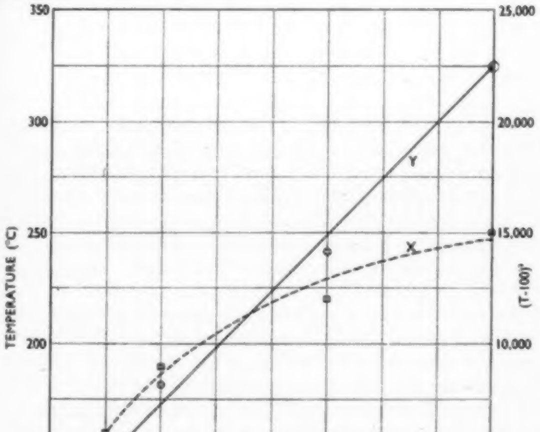

Fig. 7.—Relationship between annealing temperature and thickness of diffusion layer. Curve X: T; Curve Y: $(T-100)^2$.

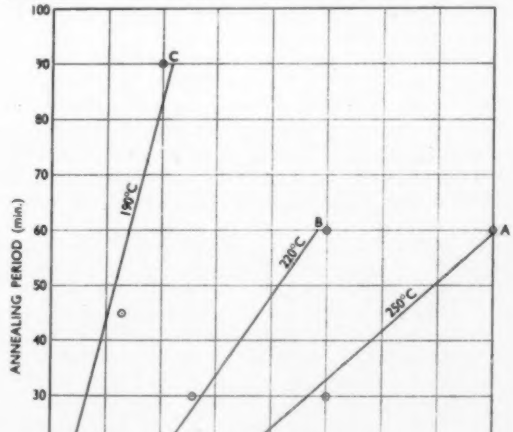

Fig. 8.—Relationship between annealing time and thickness of diffusion layer.

form the η-phase, these terminal phases undoubtedly being separated by narrow bands of the intermediate phases. When annealed for moderate periods of time at low temperatures, or for shorter periods of time at higher temperatures, the γ- and ϵ-phases are predominant, but such a condition is essentially unstable since even at lower temperatures it appears that all the copper would, in time, diffuse into the zinc to form the η-phase. When the progress of diffusion passes beyond the layer of columnar crystals of the zinc-rich phase, the presence of the aluminium-rich phase would undoubtedly introduce complications, since copper-aluminium phases would be formed. Under such conditions the simple approximation, $W = C\ (T - 100)^2$, correlating thickness of alloy layer with annealing temperature is unlikely to hold good. This relationship is, of course, empiric, and is only applicable in the present case because the amount of diffusion that occurs at 100° C., in short periods of time is negligibly small.

The results obtained from the experiments described confirm the published statement[2] that polishing of the surface prior to plating decreases the rate of diffusion, but, in addition, the present results indicate that this effect is not very noticeable at temperatures above about 200° C. A possible explanation of this phenomenon is that polishing produces a layer of cold worked metal at the surface in which the lattice is in a state of strain. In such a lattice the mobility of atoms is considerably restricted ; hence it is more difficult for foreign atoms (copper in the present case) to penetrate the lattice by substitution. At higher temperatures the annealing effect removes the strain from the cold-worked layer, hence the less marked effect of polishing on the rate of diffusion at these higher temperatures.

Oplinger reported that overcleaning resulted in an increase in the rate of diffusion between the copper electroplate and the zinc alloy. His conclusion has been confirmed by the present experiments, although it was noticed that the rate of diffusion in specimens thus cleaned was rapid initially but tended to decrease when the specimens were annealed for longer periods of time.

The explanation of this second point may be that the bonding between copper plate/alloy layer and alloy layer/zinc alloy becomes weakened during the process of rapid diffusion, with a resulting tendency for the layers to part. Due to differences in coefficients of thermal expansion, slight fluctuations in temperature may set up stresses between the various components of the electroplate and the casting and, since the alloy layer is the most brittle, fracture is most likely to occur in this zone. Such an occurrence becomes more probable when the alloy layer is thicker, since the system is then more rigid. Diffusion is not possible unless there is intimate contact between surfaces, hence the decrease in the rate of diffusion with longer annealing periods in the case of overcleaned specimens.

An explanation for the general effect of overcleaning on the rate of diffusion is more difficult to find. It is possible that the adsorption of hydrogen into the surface of the casting during cleaning activates this zone, so that the copper atoms can the more readily enter the zinc lattice, but there is no very convincing theoretical justification for this view.

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2 Anderson, A. E., and Reinhard, C. E. *Monthly Review Amer. Electroplaters Soc.*, **27**, 175, 1940.
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The Northern Flexible Centre

To meet the heavy demands made on the " flexible " advisory service of Compoflex Co., Ltd., by industry in the Midlands and North of England, the company has opened a Northern Flexible Centre at its factory in Huddersfield Road, Oldham.

The centre, which was officially opened last month by Mr. Ian Horobin, (Member of Parliament for Oldham East) is staffed by a team of specialists able to give advice on the most suitable flexible tube or hose to use in any given situation. A development section has also been started in Oldham, to deal with the design of special flexibles for particular projects. On the walls of the new centre are large photographs representing each branch of industry, with the various flexibles used in that branch displayed beneath.

The first Flexible Centre was opened by Compoflex Co., Ltd., at the Head Office in London (26, Grosvenor Gardens), in 1952, and the advisory service has since proved so popular that the opening of an additional centre in the North has become essential.

British Melting Furnaces for India

An order valued at approximately £115,000 for electric melting furnaces has recently been placed with Birlec, Ltd., Birmingham, by Tata Locomotive & Engineering, Co., Ltd., India. The order, which was obtained in the face of competition from global tenders, calls for two 4-ton and two 7-ton capacity Birlec Lectromelt electric arc furnaces to produce high-grade iron and steel for use in their new foundries at Jamshedpur. The geographical location of these works presents special difficulties as they are situated in a region where ambient temperatures as high as 120° F. and humidities approaching 100% sometimes occur. Delivery of the furnaces and the ancillary electrical gear is to be made during the summer of 1955, erection being carried out by local labour with the advice and guidance of Birlec technicians, and with the co-operation of the Company's India agents, Thomas W. Ward (India), Ltd.

The Cardiff Office of Babcock and Wilcox, Ltd., formerly at 102, St. Mary's Road, has been transferred to 26, High Street, Cardiff. The new telephone number is Cardiff 29366.

Mechanisation of Argon Arc Welding

The inert-gas-shielded welding processes have made rapid progress in the last few years, particularly in the field of light alloys. In the present article attention is directed to the mechanisation of these processes, whereby welds which are more uniform in quality and dimensions are obtained as a result of the closer control of welding conditions.

THE inert-gas-shielded welding processes, introduced into this country in recent years, have rapidly been acknowledged as having considerable advantages, particularly for the welding of light alloys. Their use for this purpose has been the subject of an intensive development programme at the Luton Establishment of Messrs. D. Napier & Son, Ltd., their mechanisation receiving particular attention. Both the tungsten electrode and consumable electrode processes are in use, and this article is primarily concerned with the development of equipment for mechanised application of these processes.

Most of the work has been undertaken on the heat-treatable aluminium alloys H10 and H15, both of which are hot-short and present some difficulty when butt-welds several feet long require to be made. By mechanisation, welding conditions may be closely controlled and repeated, welders more rapidly become proficient, and the welds are more uniform in quality and dimensions.

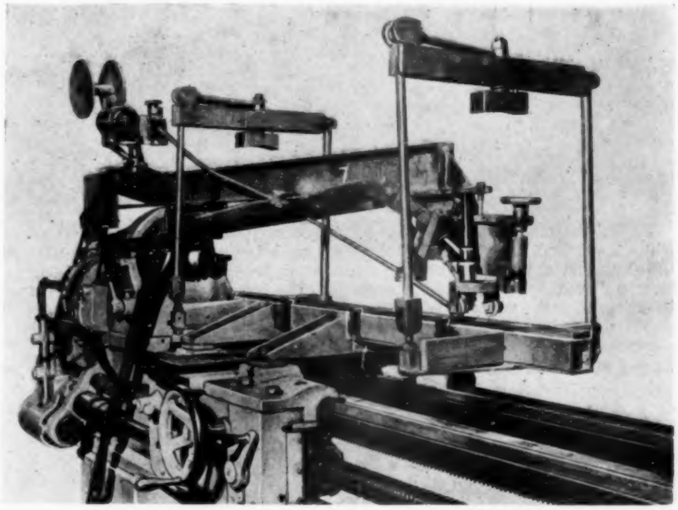


Fig. 1.—Early longitudinal welding machine as originally adapted for cylinder welding. This machine was later modified for development work. (See Fig. 2.)

Early work proved that vibration was one of the most serious obstacles to satisfactory mechanical welding, and steps have been taken on all recent equipment to deal with this problem. Whereever possible, the work is traversed under a stationary torch, and rubber couplings have been incorporated into the work-traversing mechanism at all points where parts are rotating sufficiently rapidly to set up vibratory disturbances.

Instability of the arc, which is a frequent cause of faulty welds, can be due to a number of factors besides vibration. The magnetic field associated with the arc can induce instability if there is a lack of symmetry in the disposition of ferrous materials adjacent to the line of welding. Jigs and backing arrangements should, therefore, be set out with careful attention to this point. A further cause of faulty welds, connected with material preparation, is discussed later.

These limitations led to experiments to determine the relative merits of welding from the inside, with external backing, or vice-versa. It has been established beyond doubt that inside-outwards welding is the better method, as the component, when heated during welding, expands into more intimate contact with the backing bar. Particularly in the case of circumferential welds, the result is a neater weld and a more accurate product.

Welding Machines

Fig. 1 illustrates an early machine for longitudinal welding which was adapted from a lathe. The tailstock and compound slide rest were removed, and a cantilever beam was mounted over the headstock to form a support for the torch, which may be seen, secured to a pivoted plate incorporating guide rollers. These are in contact with the work during welding, and maintain the arc gap at a preset dimension. The filler rod feeding arrangements may also be seen in the illustration, stainless steel tube extending into the argon envelope around the weld protects the wire against atmospheric contamination. Originally chain-driven, this machine has been converted to a gearbox and shaft drive, and in the form shown in Fig. 2, it is now used for development work on flat test plates.

For production welding, it has been replaced by the machine depicted in Fig. 3. Once again a lathe bed has been used as the basic structure, but in this case all parts except saddle and lead screw were removed. The stationary torch is mounted centrally in the box-section light alloy beam which runs the full length of the machine and is strongly supported at both ends. One end support may be lowered to permit the introduction of the work into the support cradle, in which it is secured by pneumatic clamping. The wire feed unit is housed in the beam, at the far end, and its control, together with others for traverse rate, arc length, etc., is brought to a common operating position. Steplessly variable current and traverse-rate controls are provided, the former by a remotely operated phase-shift system, and the latter by means of a Kopp Variator.

Mechanised circumferential welding is performed on the machine shown in Fig. 4. This machine, too, is

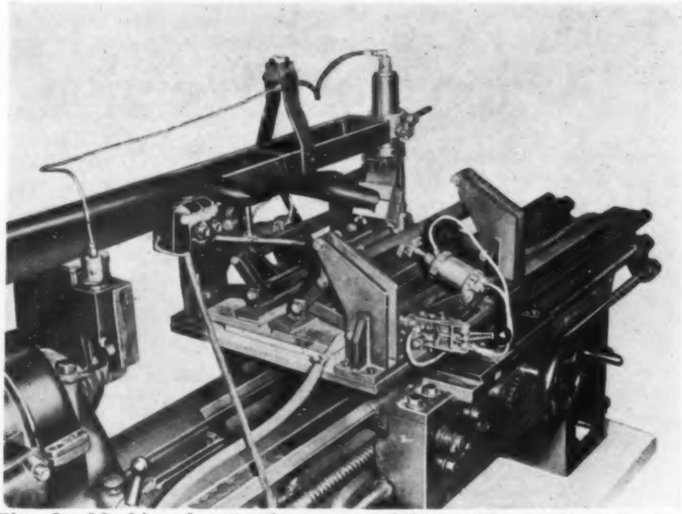


Fig. 2.—Machine for development welding. The work-table is arranged for flat test pieces, and there are facilities for controlled pre-heating and for rapid interchange of backing bars. All welding conditions are widely variable, and cover the requirements for Argonarc and Argonaut processes.

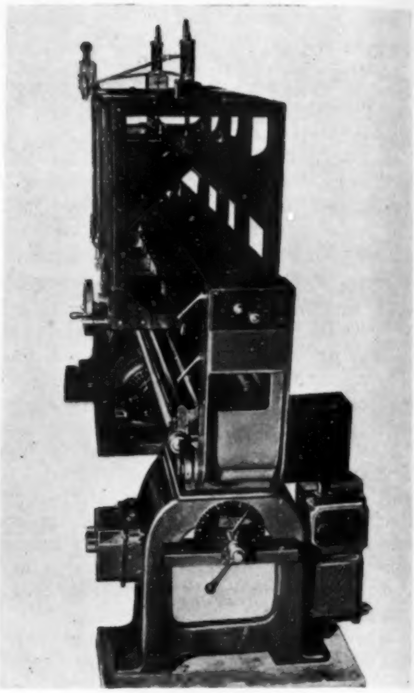


Fig. 3.—Longitudinal welding machine currently used for production of cylinders. The box beam, which is hollow and of light alloy, houses the torch and filler rod feed.

based on a lathe, to which has been added a supplementary headstock spindle, thus extending its capacity. The drive is through all the lathe gearing onto the lead-screw, whence the motion is transmitted by chains to the faceplate. In this way, a wide range of rotary speeds is available, supplemented by the inclusion of a Kopp Variator which gives the stepless control required for a special welding technique described later. Filler rod is fed to the weld from the rear, as depicted in the illustration, where the machine is set up for inside-outwards welding of a flange on to a small spun tank.

In mechanical welding, as many as possible of the controls should be steplessly adjustable, preferably whilst welding is in progress. This has been achieved in the case of all variables, welding current being drawn from either the phase-shift controller previously mentioned or from a motorised moving core reactor. Both these control systems were devised and manufactured by the English Electric Co., Ltd. Kopp Variators, incorporated into all welding machines, give stepless control of traverse rate; and arc length and filler rod feed are also continuously adjustable.

It has been found that high rates of traverse lead to porous welds. This is thought to be due to gases released from the materials being trapped by the rapidly-solidifying weld metal. It is certain that a reduction of traverse speed does bring about an improvement in weld quality. This phenomenon is not so much a feature of consumable electrode welding as it is of the tungsten argon arc process.

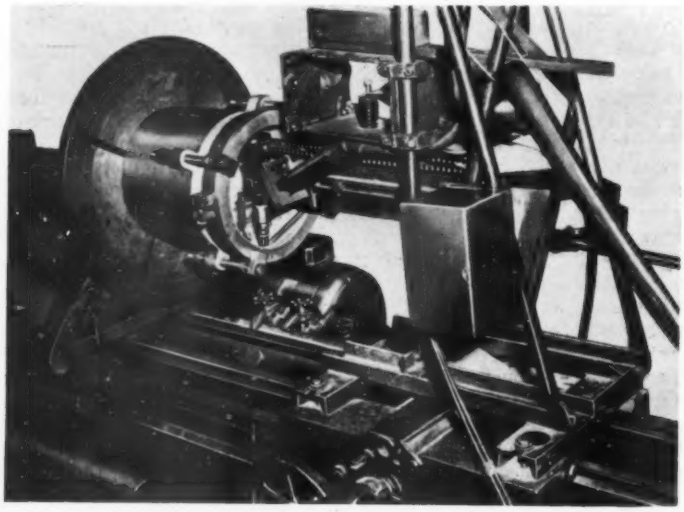


Fig. 4.—Circumferential welding machine showing elevated faceplate and adjustable torch support, accommodating a range of diameters and weld positions. The machine is set up for inside-out welding.

Of several arc-length control systems in use, that depicted in Fig. 5 is of particular interest. It is a closed hydraulic circuit, each end of which is a flexible metal bellows. Axial compression of one bellows by a cam causes an equal extension of the other, and this is used to adjust the height of the torch relative to the work. The advantage of this system over one using mechanical linkages is that, although there may be a considerable distance between the control point and welding torch, no backlash is encountered.

Until 500-amp. American welding torches became available, high welding current values made it necessary to develop special torches for this work. The two latest

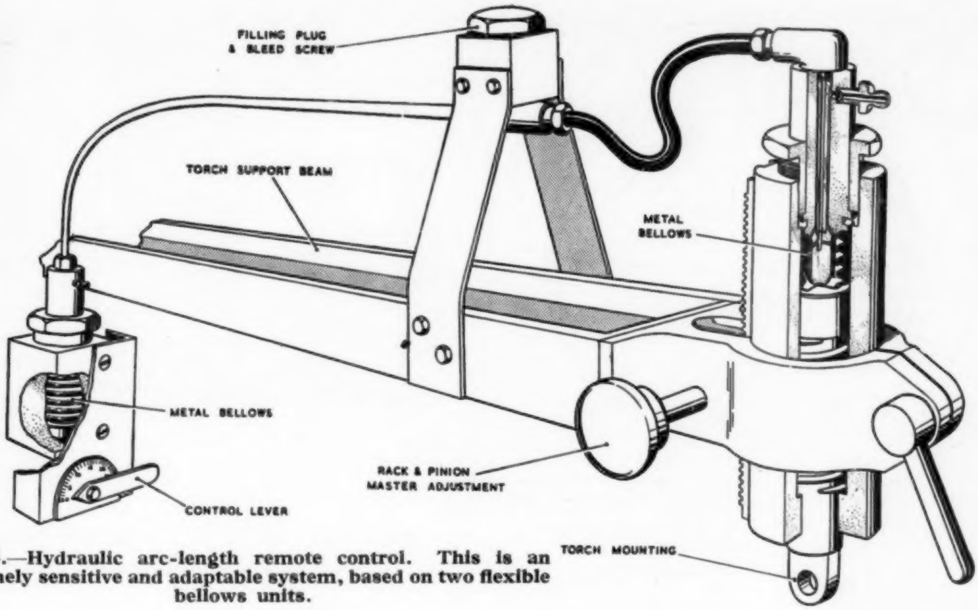


Fig. 5.—Hydraulic arc-length remote control. This is an extremely sensitive and adaptable system, based on two flexible bellows units.

designs are depicted in Fig. 6. These torches have proved themselves able to carry a continuous welding current of 800 amp., and with them it has been possible to produce single-pass 90° close-butt welds in HP10 plates $\frac{3}{4}$ in. thick. No vee preparation of the edges was necessary, and a typical weld, made at $1\frac{7}{8}$ in./min., is shown in Fig. 7.

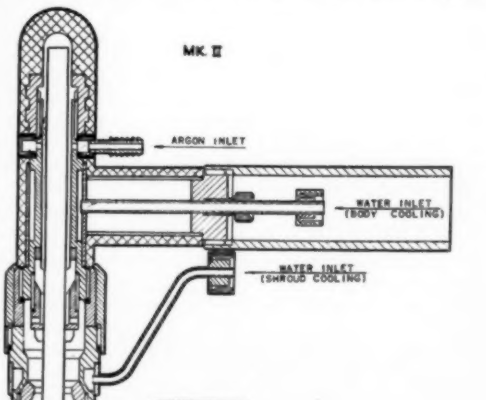


Fig. 6.—Two recent welding torch designs, both capable of handling 800 amp. continuously. The later design incorporates improved collet type, and is more compact. (Handle of Mk. III torch is omitted.)

Practical Aspects

Table I shows a number of typical settings which have been used with successful results. It should be noted, however, that it is seldom possible for other users to adhere to recommendations such as these, since size and shape of work-piece and jigging arrangements all affect the conditions ultimately chosen. Each assembly requires individual treatment, and it is normally necessary to carry out tests to obtain optimum settings.

Backing bar design is a subject on which much work has been carried out, and certain aspects of the matter are still being investigated. The result of experimental work to date is that the best form of backing bar incorporates a groove of circular arc form, 0·070–0·080 in. deep in the centre, the groove width being 0·35 in. Mild steel has been found suitable as a backing bar material for use with light alloys, and it must be remembered that expansion of the bar takes place during welding. It should, therefore, be fixed rigidly at only one

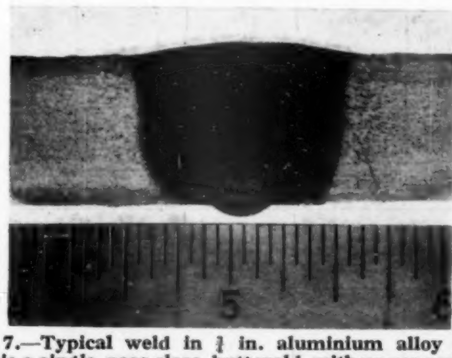


Fig. 7.—Typical weld in $\frac{3}{4}$ in. aluminium alloy plate. This is a single-pass close-butt weld, with no vee preparation, made at $1\frac{7}{8}$ in./min. and 690 amp.

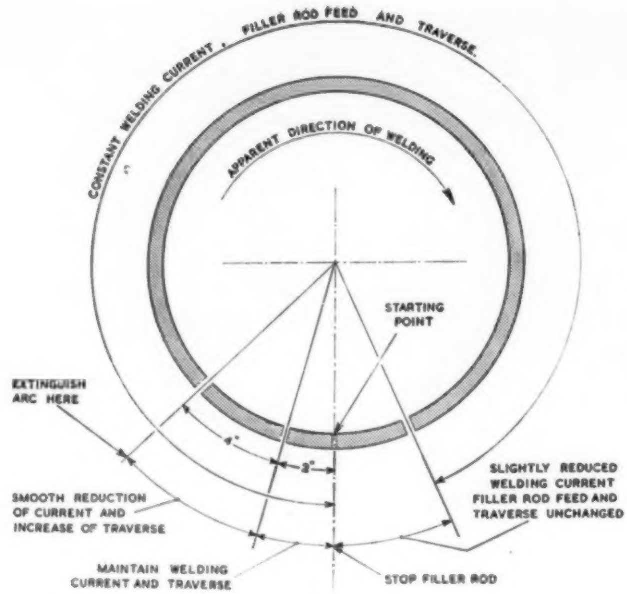


Fig. 8.—Crater-free circumferential weld. The diagram is a graphical illustration of the technique, and on the right may be seen the neat result of its application.

point; side clamping, such as may be seen in Fig. 1, allowing expansion to occur without buckling.

By itself, suitable tooling is not enough to ensure a satisfactory weld. Attention must be paid to the preparation of the edges to be joined, as very poor welds will result if they are left rough-cut with a varying gap between them. The butted edges of the work should be machined parallel, and it is vitally important that the two components should present a flat surface within 0·10 in. at the line of weld. If, due to differing thickness of material or poor jigging and fit-up, these conditions are not met, severe centreline porosity can result.

It has been found that with a 90° close-butted form of edge preparation, single-pass full penetration welds may be made on material whose thickness lies between $\frac{1}{8}$ in. and $\frac{3}{4}$ in., having regard to availability of appropriate equipment. Thinner materials have been successfully butt-welded, down to 16 s.w.g., but a lipped edge preparation is more satisfactory in these cases. The above remarks apply to tungsten arc welds only, a vee preparation having been found necessary for consumable electrode welding of all except the thinner gauges. Single-pass welds by this process are, in our experience, limited to a thickness of $\frac{3}{16}$ in. above which a multi-run method should be employed.

It will be found useful in some cases to tack-weld the parts together by hand before mechanical welding, but tack-welds are not strong enough to maintain the close-butted edges unaided, and mechanical clamping of the work is always necessary. If accurate fit-up of the parts can be achieved by mechanical means, it is considered preferable to omit tack-welding altogether.

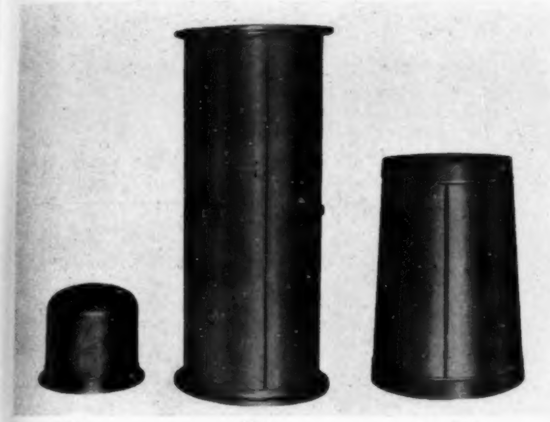
Following the techniques of tooling and edge-preparation already described, welding together of wrought and

TABLE I.
(a) TUNGSTEN ARC WELDING.

Material		Current (amp.)	Transverse Rate (in./min.)	Filler Rod			Electrode Diameter (in.)	Argon Flow (cu. ft./hr.)	Remarks
Specification	Thickness (in.)			Specification	Diameter (in.)	Feed (in./min.)			
NP6	0·5	635	3	NW6	$\frac{1}{8}$	12/14	[illegible]	22	Two Pass
			3	—	—	—	[illegible]	22	
NP6	0·75	690	1[illegible]	NW6	$\frac{1}{8}$	8	[illegible]	24	Single Pass
NP6	0·75	720	1[illegible]	NW6	$\frac{1}{8}$	6	[illegible]	24	Single Pass
HS15	0·192	297	4[illegible]	HW15	$\frac{1}{8}$	10/12	[illegible]	23	Single Pass
D.T.D.687	0·192	300	5	D.T.D.683	$\frac{1}{8}$	14	[illegible]	23	Single Pass (Unclad Material)
HP10	0·3	485	4[illegible]	D.T.D.245	$\frac{1}{8}$	16/18	[illegible]	20	Single Pass
HS10	0·128	300	4[illegible]	D.T.D.245	$\frac{1}{8}$	16/18	[illegible]	20	Single Pass
ZW3	0·75	585	4[illegible]	Z2Z2C	$\frac{1}{8}$	20	[illegible]	30	Single Pass
ZW3	0·5	550	4[illegible]	Z2Z2C	$\frac{1}{8}$	28	[illegible]	30	Two Pass Alternate Sides
		433	4[illegible]	Z2Z2C	$\frac{1}{8}$	24	[illegible]	30	
ZT1 and ZRE1	0·25	400	10	Z2Z2C	$\frac{1}{8}$	19	[illegible]	30	Single Pass

(b) CONSUMABLE ELECTRODE WELDING.

Material		O.C. Voltage (volt)	Arc Voltage (volt)	Current (amp.)	Filler Rod			Argon Flow (cu. ft./hr.)	Remarks
Specification	Thickness				Specification	Diameter (in.)	Feed (in./min.)		
HS10	0·25	80	26	240	HW15	1/16	235	60	Single Pass Auto.
HP10	0·5	80	23	260	D.T.D.245	1/16	230	60	Three Pass Man.
HS10	0·192	80	25	270	D.T.D.245	1/16	235	60	Single Pass Man.
HS15	0·192	80	25	260	HW15	1/16	230	60	Single Pass Man.



(a) (b) (c)

Fig. 9.—Typical welded fabrications. Three representative components are depicted, all welds being readily visible.

cast components has been undertaken with success, and several fabrications comprising rolled or spun sheet are being welded to cast flanges and other details. In this connection, castings in D.T.D.245 are welded to HS10, using aluminium-11% silicon filler rod (D.T.D.245 composition). The same filler rod is used for HS10/HS10 work, while that employed in welding HS15 material is of parent metal composition. Preliminary work on D.T.D.687 type alloys (unclad) indicates that these materials can be welded successfully with filler rod of the same composition.

A development programme on the welding of magnesium-based alloys, indicates that all those tested, except Elektron Z5Z, are mutually weldable, using filler rod to specification Z2Z2C.

Special Techniques

During the development work with which this article is concerned, certain special techniques were evolved, two of which may be of particular interest. The first concerns the production of circumferential argon arc welds free from the deep finishing crater normally found at the end of a run. In this special technique, the weld is initially made in the normal manner with filler rod addition. When the work has completed a revolution under the torch and the original starting point is reached, the filler rod feed is stopped, and rotation of the work under the arc is continued. After an overlap of about $1\frac{1}{2}$–2 in., the welding current is smoothly reduced, and at the same time the electrode is raised and the traverse speed increased, with the result that penetration is progressively lessened. At the moment of extinction of the arc the depth of molten metal does not exceed $\frac{1}{32}$ in., and the minute crater which results is totally contained in the built-up metal formed during the first run. Fig. 8 illustrates this technique and shows the neat result of its application.

Fig. 10.—Application of bosses to cylinder wall. A section through the applied boss shows how full penetration welds have been achieved.

Another special process which has been developed is used for the addition of lugs to the wall of the pressure cylinder in Fig. 9. Fig. 10 is a section through the weld, illustrating the complete fusion which is obtained. The method is to trepan a hole in the cylinder wall and insert a cast part which comprises the necessary projections, together with replacement material for the portion of cylinder wall which has been removed. A full-penetration weld is then made around the periphery. The cylinder material is HS10, and the insert is to specification D.T.D.245, with the latter material as filler rod. To meet design requirements, the tensile strength of the material has to be restored, and this is achieved by heat treatment. A process employed for accurate sizing of cylinders produced by welding has been incorporated into the heat treatment cycle, in the following way.

H10 and D.T.D.245 materials both respond to a two-part heat treatment operation embodying solutionising at 535° C. and, after quenching in water, precipitation at 170° C. As soon as the solutionising process is completed, the component is removed from the furnace and placed over a cast iron or mild steel mandrel as quickly as possible. Both cylinder and mandrel are lowered into the water quenching tank, and the chilled cylinder shrinks into intimate contact with the mandrel. They are then replaced in the furnace for precipitation. During this process, the expansion of the light alloy relative to the mandrel at the treatment temperature is sufficient to free it, thus allowing easy removal. Cylinders 18 in. in diameter and 4 ft. long have been trued up in this manner in two stages on successively larger mandrels, the result being a product which is completely straight, and on which a diameter tolerance of plus or minus 0·005 in. may be held. Fig. 11 illustrates a cylinder undergoing this treatment, and shows one of the mandrels used. As far as restoration of mechanical properties is concerned, Table II gives details of typical results achieved.

TABLE II.—TYPICAL MECHANICAL PROPERTIES OF LIGHT ALLOY BUTT WELDS AFTER HEAT TREATMENT.

Parent Material		Filler Rod	Welding Process	Properties—Fully Heat Treated					
				Specification			Welded		
A	B			U.T.S. (tons/sq. in.)	0·1% P.S. (tons/sq. in.)	El %	U.T.S. (tons/sq. in.)	0·1% P.S. (tons/sq. in.)	El %
HS10	HS10	HW10	Tungsten	19	15	8	20·8	17·0	4·0
HS10	HS10	D.T.D.245	Tungsten	19	15	8	20·7	18·5	2·0
HS15	HS15	HW15	Tungsten	26	20	8	28·2	21·02	4·0
HS15	HS15	HW15	Consumable Electrode	26	20	8	29·6	24·3	5·1
D.T.D.687	D.T.D.687	D.T.D.683	Tungsten	32	27	8	32·6	29·7	1·5

The D.T.D.687 material was unclad.

Fig. 9 illustrates three typical light alloy fabrications, the flanges being of cast D.T.D.245 attached to the wrought components (of HS10) by circumferential welds. Items (*a*) and (*b*) are required to sustain high internal pressure, and all must conform to close dimensional tolerances. Item (*a*) is produced as a 10 s.w.g. HS10 spinning, and the position of the weld indicates that the flange incorporates a portion of the body, making a butt-welded joint possible. The circumferential welds on item (*b*) are similarly placed, and in this case the wall thickness of the vessel is 0·3 in. Item (*c*) of Fig. 9 is a unit which is mechanically welded using the argon arc process, and although not pressurised, is a structural component in which dimensional accuracy is vitally important.

Fig. 11.—Heat treatment and sizing. Part of the heat treatment shop, showing pit furnace, sizing mandrel and typical work-piece in lifting tackle. The groove in the mandrel accommodates the weld bead, which is removed at a later operation.

Design Aspects

Mechanised welding is a specialised subject, and its requirements should be understood by those responsible for designing components on which it is to be employed. They should be advised of the dimensions of welding torches and, where necessary, of welding machinery, so that joints are placed where access to them may most conveniently be obtained. Drawings should indicate clearly from which side the weld is to be made, and designers should bear in mind the fact that it is going to be necessary to apply and remove a backing bar. They should also consider the special provisions which it may be necessary to make to allow for machining after heat-treatment. It has been established that the most satisfactory form of argon arc weld is the full penetration, 90° close-butted joint, fillet welds being avoided wherever possible. Not only is this type of weld better from the point of view of radiological and visual examination, but the chances of success in obtaining a sound joint are considerably improved.

Alongside the current production programme, development work related to mechanised welding continues, and a number of interesting problems are under investigation. Included in this work is the development of a technique for producing crater-free longitudinal welds, so that a scrap allowance need not be made at the ends of the component. Work is also in progress on a series of experiments which are in the nature of a research into the fundamentals of argon arc welding of light alloys, so that the scope of mechanisation may be increased.

Tinplate Annealing Line for Velindre

DAVY-UNITED have received an order from The Incandescent Heat Co., Ltd., for the supply of the mechanical equipment required for a continuous tinplate strip annealing line which Incandescent are supplying to the new Velindre Works of the Steel Company of Wales, Ltd. It will be the first line of this type operating on tinplate in Europe.

The strip intended for use as tinplate ranges from 0·007 in. to 0·018 in. in thickness, and is rolled down almost to final size in either a tandem or reversing cold mill from hot rolled material having a thickness up to 0·100 in. The heavy reductions involved cause a work-hardening effect which must be eliminated by annealing, but before this can be done the strip must be cleaned to remove all traces of roll coolant and lubricant.

Normal practice has been to remove the palm oil lubricant and coolant in an electrolytic cleaning line, wherein the strip is rewound into coil form, and then to stack these coils in an annealing furnace. This is of course a batch process. A later development in the U.S.A., however, brought into use a continuous annealing line where the strip passes through a cleaning section and then through a furnace section made up of heating, holding and cooling zones. The strip moves continuously through these sections and the loss of time due to loading and unloading batch type furnaces is therefore avoided. Further savings in time and labour also result from the combination of cleaning and annealing in one single processing line.

Several such continuous lines are now in operation in the U.S.A. The line destined for Velindre, which will be the first of this type in Europe, will be working in conjunction with a 5-stand tandem cold strip mill and two 2-stand skin pass mills which Davy-United are already building for these new works. Strip to be handled on the line will range from 19 in. to 38 in. in width and from 0·007 in. to 0·024 in. in thickness; it will be supplied in coils weighing up to 36,000 lb. each and having a maximum outside diameter of 76 in. The top operating speed of the line will be 700 ft./min. in the process zone, and the output when dealing with strip 30 in. wide × 0·010 in. thick will be 16½ tons/hr.

K.G.S. Telex

THE K.G.S. Bearing Co., Ltd., are now on the G.P.O. Telex service, their number being 33–214. This system has been in use between Great Britian and the Continent for some time now, and is to be extended to include a communication system between subscribers in Great Britain towards the end of the year.

Developments at Consett Iron Works

Iron and Steel Engineers Meeting at Newcastle

For many years, particularly since 1945, continued progress has been made in efforts to increase production at the works of the Consett Iron Company. Development schemes put in hand are now operating and the results are so satisfactory that recently a three-day meeting of the Iron and Steel Engineers Group of the Iron and Steel Institute was held at Newcastle upon Tyne, by invitation, at which technical aspects of the developments were presented by members of the Company's staff. In addition, arrangements were made for visits to see the works at Consett, the ore discharging facilities at Sutherland Quay and the Jarrow works of the Company. Here the object is to review in outline the developments that have taken place.

SOME two hundred members of the Iron and Steel Engineers Group of the Iron and Steel Institute were the guests of the Consett Iron Co., Ltd., at a recent meeting held at Newcastle upon Tyne. The meeting was devoted to the presentation and discussion of seven technical papers on developments at the Consett Works, each of which was given by a member of the Company's staff. In addition there were visits to the works at Consett and Jarrow, and to the ore discharge terminal at Tyne Improvement Commissioners Quay, Tyne Dock—the latter visit by kind permission of the Tyne Improvement Commission—and a dinner was held at the Royal Central Hotel, Newcastle upon Tyne, at which Mr. Harold Boot, Managing Director of the Company, presided.

The Consett Works

The Consett Works now cover over 650 acres and employ more than 6,000 men; they are completely integrated from coke production to finished rolled products, and are independent of any outside source of supply of electricity. Originally the formation of the Derwent Iron Company, in 1840, created the foundations upon which the Consett Iron Works are built. This Company took leases of ironstone and coal royalties and, although local ironstone existed at that time, the coal royalties were undoubtedly the main reason for the location of the works at Consett. The undertaking was acquired by the present Company in 1864, at a time when the yearly output was about 80,000 tons of pig iron and between 40,000 and 50,000 tons of finished iron. Subsequently the record of the Company has been one of progress. Each of the original blast furnaces produced approximately 230 tons of iron per week, and in 1865 a larger furnace, producing about 340 tons per week, was added. During the following years, all the old furnaces were pulled down and six larger furnaces, each with a capacity of 750 tons of iron per week, were substituted: in 1880 a seventh blast furnace was installed.

Supplies of hematite ore had been obtained from Cumberland and Lancashire, but in 1872 the Company became associated with others in the formation of the Arconera Iron Ore Co., Ltd., which acquired large hematite ore mines at Bilbao in Spain. For many years the Consett Iron Company was guaranteed large supplies of ore from this source until, in 1948, arrangements were made for the Arconera mines to be acquired by a Spanish company. Although the Consett Works are located nearly 1,000 feet above sea level, and some 20 miles inland, it will be noted that for a considerable number of years ore supplies have been imported.

During the period 1876–1880, the Company's output of iron plates and rails frequently reached 2,000 tons per week, but it soon became evident that steel would displace malleable iron for shipbuilding and rails, and by 1883 two small 13-ton Siemens furnaces were operating for the manufacture of steel. Shortly afterwards four 17-ton furnaces were installed, and later another two of the same size were added. The Company continued to expand rapidly and by 1893 it was regarded as a very large undertaking. At that time it was operating ten collieries with an annual output of coal in the neighbourhood of a million tons. Some of this was exported but a great deal was carbonised in 1,050 beehive coke ovens, which produced about 500,000 tons of coke annually.

The present major reconstruction and development scheme, which was started by the erection of No. 2 blast furnace in 1943, is the third in the history of the Company; the first was the installation of the old angle mills in 1893, and the second the erection of the present melting shop and plate mills, completed in 1925. Templetown brickworks were originally erected to supply bricks and shapes for a new coke-oven plant at the Fell Works—the first all-silica coke-oven battery in Europe—which was put into operation in 1924, and which has since operated continuously and efficiently.

For several years prior to 1938 there was a lull in the development of the steel industry as a whole, although much reconstruction and expansion had been planned. There were several reasons for this, notably the financial stringency following the years of depression, the uncertainty concerning heavily subsidised foreign competition, and political squabbles involving the industry. These were of great influence in curbing the enthusiasm for development of many steel firms. When, in 1938, rearmament began and various iron and steel firms put their reconstruction schemes in hand, the Consett Company was not behind in plans designed to carry forward and improve upon the major developments completed in 1925. In spite of war and the preparation for war, from the beginning of 1938 until 1943, a Thiessen gas cleaning plant, a blast-furnace gas-holder, a pig-casting machine, a sinter plant, ore-handling plant, and a completely modern mechanically-charged blast-furnace were installed and put into operation.

The conserving of vital materials for war necessarily interfered with further development, but for some considerable time before the war ended plans were under consideration. Even under the difficulties of war, however, it was found possible to convert the mill reheating furnaces to mixed blast-furnace and coke-oven gas firing, so that at the end of the war the only remaining gas producers were in the melting shop.

With the change in government at the end of the war, and the likelihood of the nationalisation of the coal mining industry, it was felt that the Company might be faced with the prospect of much dearer coal and, perhaps, much less of it. It seemed clear, therefore, that the future plant must be designed around economy in fuel as a major factor, and the ideal aimed at was a plant in which the only coal used was that charged into the coke ovens for making coke for the blast furnaces. This became evident when the mining industry was nationalised, involving Consett not only in the loss of all its coal-producing units, but also the loss of two-thirds of its coke-producing capacity and four-fifths of its power generation.

Immediately following the conclusion of hostilities, and before final decisions were made on the proposed schemes of development, officials of the Company visited the United States of America to study American practice in blast-furnaces, melting shops and mills. As a result of this visit they were convinced that, to be efficient, a steelworks should be designed for an output of not less than 750,000 tons of ingots a year. It was upon this basis that the final plan took shape.

Extensions and Developments

Several extensions and alterations to plant and equipment were carried out together, such as increasing the coking capacity, installing modern blast-furnace units, building a new power station, and modernising the open-hearth furnaces. Many auxiliary changes were included, such as water-cooling of open-hearth furnace doors and door frames, a new rising main from the low- to high-level reservoirs, new mains from the latter to the blast furnaces, and pumping plant and mains to take blast-furnace cooling water to the melting shop for further use. Also necessary were pumping plant and mains to bring water from the river Derwent to the low-level reservoirs, new sewers, main drains, complete new cables and cable runs, switchgear, etc., and works amenities, such as canteens and rest rooms.

Coke Ovens, Blast Furnaces and Power Station.

To help in restoring the coking capacity of the Company to 18,000/20,000 tons per week, the Fell battery of Wilputte ovens was extended by the erection in 1949 of 54 Becker ovens fired by blast-furnace gas. The replacement of the first section of Wilputte ovens has now been completed and a further battery of 17 Wilputte ovens installed.

The new power station supplies all the electricity required for the new works, all the air for the blast furnaces, and all the process steam for the Fell ovens, etc., and replaces all the old boiler and power plant at the blast furnaces.

Two further modern blast-furnace units have been built to make a three-furnace plant. With these there has been a complete renewal of all mains and cables and the building of a new gas-cleaning plant to deal with the larger volume of blast-furnace gas. In addition, a conveyor belt to transport coke from the ovens direct to the blast furnace plant has been installed.

Steel Plant.

The melting shop, originally built in 1925 with eight 75-ton producer-gas fired open-hearth furnaces and a weekly capacity of 7,500 tons of ingots, has been modernised and now has seven 150-ton basic hearth furnaces and one 80-ton acid hearth furnace, all fired with a mixture of coke-oven gas and tar. These were completed in 1951 and provided facilities for an output of 12,000/13,000 tons of ingots per week. This part of the scheme also included the provision of a 1,000-ton capacity inactive hot-metal mixer. Adjacent to the mixer at one end of the melting shop is located the Bessemer plant, comprising two 25-ton acid Bessemer converters. In order to increase the steel output to 18,000 tons per week it was decided, under the conditions at Consett, to make use of the Duplex process, by which carbon, silicon, etc., are removed from molten iron in the acid converters and the finishing and refining subsequently carried out in the open-hearth furnaces. This augments the work of the open-hearth furnaces and enables increased output per furnace to be obtained.

Rolling Mills.

With the increase in ingot capacity, and in conformity with the overall scheme, additional billet and slab-rolling facilities have been provided to increase the finishing capacity of the works. The new rolling mill plant installed comprises a Davy-United high-lift blooming and slabbing mill, followed by a Morgan continuous billet and slab mill of ten stands, arranged in two separate groups of six and four stands respectively. The blooming and slabbing mill is designed for an output of 22,000 tons per week of blooms and assorted slabs, and is equipped with a bloom and slab shear capable of cutting the full range of products from the mill. A side transfer for slabs to feed the existing plate mills forms part of the equipment, comprising transfer bank, assembly tables, piler table and an electrically driven pusher. From the piler table the slabs are transported by rail bogie to new continuous slab reheating furnaces in the plate mills.

The six-stand Morgan continuous billet and slab mill is designed for the production of a wide range of billets ranging between 3½-in. and 9-in. square section and slabs ranging from 24 in. to 9 in. in width down to 2½ in. thick. The four-stand mill produces billets ranging from 3½ in. down to 1¾ in. square section and small slabs from 8 in. by 2 in. down to 4 in. by 1½ in. The plate mills are supplied with slabs from the first side take-off of the new slabbing mill, while a proportion of the output from the four-stand group is used to supply the Morgan bar and strip mills at the Jarrow works.

A particularly novel feature about the layout of the Consett Works is that the new slabbing, blooming and continuous billet mills have been erected over a branch line of British Railways, the mill floor being about 35 ft. above the line: this complicated the erection of the building housing the new mills.

The whole plant is designed for 100% imported ore, and for handling this material the Tyne Improvement Commission has enlarged Sutherland Quay, Tyne Dock, to take 20,000-ton ore carriers, British Railways have provided special trains of 56-ton ore wagons, and the Company has installed modern unloading and stocking equipment.

Some Technical Aspects

Although teething troubles, inseparable from the operation of a reconstruction scheme of the size of Consett's, have been experienced, there is no doubt that the Directors and staff are very pleased, and rightly so, with their achievement. They had the necessary enthusiasm to present their experiences before the Iron and Steel Engineers Group, and the courage to raise some of their troubles for discussion.

The Duplex Process.

The Duplex process was discussed by Mr. W. E. Ward, the works production manager, who emphasised that the acid Bessemer converter plant was neither intended nor designed to use as an independent steel-making unit, but was installed to form an integral part of the open-hearth plant and, therefore, is located in line with the furnace stage. This integrated melting shop is operated to produce from the scrap available at any time the greatest possible tonnage of steel by the straight open-hearth process, using approximately 70% scrap and 30% hot metal, the difference between this tonnage and the total ingot requirement being produced by operating the Duplex process in the existing open-hearth furnaces nearest to the Bessemer plant—one, two or three of these, as required, being charged with blown metal from the Bessemer plant together with hot metal from the mixer and scrap.

Hot metal with an average composition of: 1·2% Si, 0·6–1·0% P, 0·04–0·07% S, 0·5% Mn, is desulphurised by the addition of soda ash to the ladle at the blast furnace if the sulphur content is 0·05% or over; in any case the metal is skimmed to remove slag before being poured into the mixer, which is lined with magnesite up to a level just above the slag line and roofed with firebrick. The metal is blown in the converter for eight to ten minutes with air delivered at 35,000 cu.ft./min. and at a pressure of 27 lb./sq.in. At the end of this time the silicon and manganese have been oxidised and the carbon has been reduced to about 0·1%, the sulphur and phosphorus being unaffected.

"So far as our relatively short experience allows us to form an opinion," continued Mr. Ward, "we believe that a heat consisting of 125 tons of blown metal (i.e. five blows) 35 tons of hot metal and 25 tons of scrap, which takes from 6 to 7½ hours from tap to tap, depending on the phosphorus content of the blown metal and the required analysis of the finished steel, best suits our requirements."

Notwithstanding some operating difficulties cited by Mr. Ward, he was convinced that the combination of high scrap and Duplex processes in one shop forms an amazingly flexible and satisfactory method of increasing the output of a fixed open-hearth furnace shop.

Rolling Mills Installation and Operation.

The installation and layout of the slabbing, blooming and continuous billet mills was briefly described by Mr. A. Marshall, the development engineer. Particulars were given of the stripper bay building, the soaking pit building, and the main mill buildings, together with brief information about the mills installed. He dealt in greater detail, however, with the site chosen for the erection of the plant and buildings, and discussed many of the problems involved.

Operational experiences with the new mills were discussed by Mr. A. Henderson, the mill manager. For a short period before the slabbing and blooming mill was completed, key men, recruited from the old slabbing mill, were given instruction by the engineers responsible for the erection on the use of the more important controls, and, by the time the mill was handed over to the production department, a complete shift of operators had been trained. The first operational stage provided for one shift rolling slabs for the plate mills. The second stage took shape later when a second shift was introduced in the new mill. During this stage the rolling of blooms was tried and trouble was experienced with blooms turning down in the first edging hole. This was doubtless due to the inexperience of the operators in handling 10-ton square ingots, although the heating may also have had some effect on the rolling. Rolling times were in the region of five minutes per ingot. It was decided to deepen the edging holes from 2½ to 3 in., and in the case of the 15-in. hole to introduce a convexity of ⅜ in. per roll. The result of the modifications was that all the operators produced a satisfactory bloom from a 10-ton ingot in three minutes.

One of the problems in the early stages was to roll the blooms sufficiently rapidly for them to reach the billet mill without losing too much heat. To avoid any blooms entering the first pair of rolls at too low a temperature, a temperature recorder was set up and kept under observation by one of the mill crew. Bloom temperatures of 1,000–1,050° C. were soon maintained without difficulty.

A breakdown on the slab-shear gearbox upset plans and, as the shear was expected to be out of commission for some weeks, the British Oxygen Company was called in to investigate the possibility of keeping the mill working by gas-cutting the blooms. Within 48 hours the necessary equipment to cut 9-in. by 9-in. blooms was installed and the billet mill was back on production.

Mr. Henderson also discussed soaking pit performance and gave particulars of roll life during the comparatively short time the mills have been operating, concluding with a reference to the performance of the mills. He stated that, as the mechanical stoppages have been abnormal, the shift tonnages have been seriously reduced. The necessity of having to roll plate mill slabs one shift and billets two shifts has presented difficulties in allocating the ingots to the particular shifts and a good deal of overlapping has occurred. The planning of the charging to a closed schedule has now been adopted and this is gradually overcoming the problem. Some of the tonnages which have been recorded up to date are :—

	Tons
Highest weekly throughput of ingots in 18 shifts ..	17,556
Highest weekly output of billets in 12 shifts	6,709
Highest shift throughput of ingots in 7½ hours ..	1,328
Highest shift output of billets in 7½ hours	1,054

Electrical Developments.

Some observations on the trends in electrical development, in particular those associated with the Consett Works, were made by Mr. T. Coxon, the consulting electrical engineer, who regarded it as correct to say that the increase in the use of electricity in the steel industry is related directly to the ever-increasing production of steel and, of course, to the advance in knowledge of electricity in all fields. Thus, in all branches of steel-works development an increasing percentage of capital outlay is required for electrical plant, and this can be the cause of considerable disquiet at top management level.

Five 10 ton grabbing cranes (Kangaroo type).

With the present almost bewildering rapidity of advancement in electrical technique, it becomes more and more difficult for the electrical engineer to ensure the optimum utilisation of all the electrical industry has to offer by steering a middle course, avoiding, on the one hand, the delving into the more or less unknown by introducing a multiplicity of complicated devices which in the hard and unrelenting steelworks sense are "not proven," and, on the other hand, a too conservative tendency to stick only to the "tried and true."

From all architectural and engineering standpoints the power station at the Consett Works ranks with the most modern in the country. Since it is also a turbo-blower station serving the blast furnaces, it was positioned as close to the blast furnaces as the site would permit. The installed generator capacity of 45 MW is adequate for present and immediate future requirements, and the main and auxiliary switchgear and transformers have been selected and arranged to give the highest degree of reliability and flexibility in the main control and distributing systems.

After discussing the main distribution system, Mr. Coxon outlined the major electrical developments associated with the blast furnaces (including ore handling and sinter plants); coke-oven plant; steelworks; slabbing and blooming mill and the continuous billet mill; and the Bessemer plant.

Electrical Maintenance.

On the question of electrical maintenance Mr. R. Mathieson, chief maintenance engineer (electrical), contended that choice of suitable personnel is of paramount importance in the efficient running of the plant. In this connection the most important choice is the foreman or chargehand. Given a competent foreman over each of the various sections of the plant, detailed and cumbersome paper work assumes a lesser importance. The foreman has intimate daily contact with the operation of plant and is, therefore, best informed on immediate and future requirements. It is from this source that the engineer learns of immediate or impending troubles, and of any plant peculiarities—all of which information is gathered together and recorded so that modifications can be decided upon and future planning initiated.

It is essential that the foreman should have intimate and detailed knowledge of the equipment under his control, and to do this he must have the time and facilities for the study of drawings and preparation of schemes for improvement. Neither shift men nor any other personnel can do their work unless they are given the necessary information relative to the plant they service. This passing on of information plays a larger part than is sometimes realised in the efficient running of a maintenance organisation, and its importance cannot be stressed too highly.

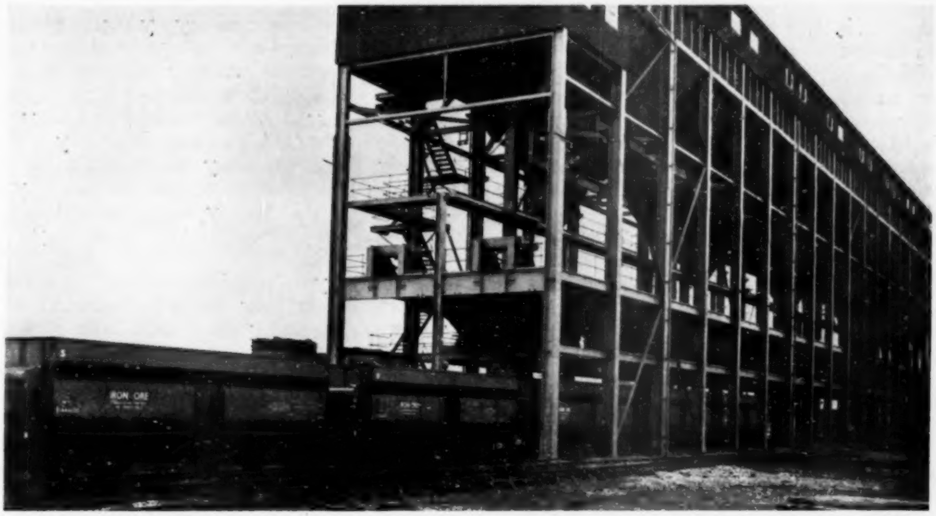
In conclusion, Mr. Mathieson was of the opinion that, in addition to adequate records, inspection schedules and stock level systems, it is necessary to be mindful of the individual. To have a department where each man feels that he is a necessary part of the whole, that the well-being of the Company, which incidentally is a measure of his own well-being, is dependent upon his own conscientious effort, and where each man has a pride in his craft and a job well done, then maintenance problems are largely already solved.

The Power Station.

A general description of the power station and its operation was given by Mr. T. F. Hutchinson, the power station manager. This new power station consists of five 120,000 lb./hr. boilers raising steam at 405 lb./sq. in. and 750° F. Nos. 1, 2 and 3 of these boilers can be fired with blast-furnace gas, coke-oven gas and pulverised coal, burnt singly or in combination. Nos. 4 and 5 are designed principally for coal firing by means of Taylor multiple retort underfed stokers, although No. 4 boiler is fitted with two blast-furnace gas burners also. All the boilers are Clarke Chapman three-drum water-tube type with water walls. Nos. 4 and 5 boilers are fitted with mixers for blending coals or blending coke breeze with coal for its efficient combustion.

There are three 15 MW 11,000 volt turbo-alternators of the condensing and pass-out type, taking steam at 400 lb./sq. in. and capable of passing out 80,000 lb./hr. of steam at 160 lb./sq. in. Two of the turbo-blowers are rated at 45,000 cu. ft./min. of air at 30 lb./sq. in., or 50,000 cu. ft./min. at 25 lb./sq. in.; and a further turbo-blower is rated at 40,000 cu. ft./min. at 25 lb./sq. in.; all for use on blast furnaces. There is also a turbo-blower rated at 32,430 cu. ft./min. at 35 lb./sq. in., for Bessemer blowing. All turbo-alternators and -blowers are of C. A. Parsons manufacture, and a fifth blower will be installed this year.

Being part of an integrated steelworks, the power station is keyed into the economy of the works as a whole, and draws its fuel from other producing departments such as blast-furnaces and coke-ovens. It can, however, operate independently of these fuels, as it carries bunker stocks of solid fuel and can at any time maintain its full rated output on coal alone. The power station, on the other hand, supplies all the electric power consumed in the works, steam for heating and process work, and all wind for blast furnaces, Bessemer converters and compressed air. Mr. Hutchinson discussed in some detail operation and maintenance, and concluded with some operational data for 1953.



Conveyor gallery showing 10 storage bins and 36 subsidiary hoppers. 56-ton wagons are being shunted into position under the hoppers.

The New Ore Handling Plant

Most of the imported ore required by the Consett Works has, in the past, been discharged at Tyne Dock. When the very considerable increase in iron and steel making was planned, special consideration was given to modern handling from ship to stocking yard of the greatly increased quantity of imported ores that would be required—some $1\frac{1}{4}$ million tons per year. Several alternatives were considered, but eventually negotiations were opened with the Tyne Improvement Commission and the British Transport Commission and a scheme approved to quicken the discharge of vessels at Tyne Dock, to speed up the transport of the ore to Consett, and to provide improved facilities for its reception there. The subject of ore handling was discussed by Mr. S. C. Pearson, the transport manager, at one of the technical sessions of the Engineers Group meeting, and, at a dinner held later Mr. B. Eliot Common, Chairman of the Tyne Improvement Commission, also discussed the project.

A new terminal to receive the ore has been built at Consett, and new wagons with a capacity of 56 tons have been put into operation by British Railways who have also provided specially equipped locomotives for dealing with the traffic. To accommodate ships with up to about 25,000 tons of iron ore, a new quay has been built with a depth alongside of 35 ft. at low water. This quay is equipped with five Kangaroo cranes, each with a lifting capacity of 10 tons. 50-ton hoppers are built in front of the crane trucks and the ore is discharged from the ship by means of grabs into these hoppers. With a time cycle of 60 seconds and a grab capacity of 5 tons, each crane can, in theory, achieve a maximum output of 300 tons per hour, giving a total output of 1,500 tons per hour with five cranes. In practice 300 tons per crane per hour has been exceeded by individual cranes.

From the Kangaroo hopper the ore is transferred by a vibratory feeder to a short inclined belt conveyor 42 in. wide and contained within the crane structure. While passing along the conveyor the ore is automatically weighed so that the output from each crane is known. The ore is carried by conveyors to the junction house at the west end of the quay, where it is transferred by means of chutes to an inclined conveyor which takes the ore to the distribution conveyor above the storage bunkers. The ore can be discharged into any one of the ten storage bunkers, each of which has a capacity of from 700 to 1,270 tons according to the density of the ore. The purpose of the bunkers is to allow the discharge of a vessel to proceed without interruption when the quantity of ore being discharged exceeds the quantity being removed by rail.

There are 36 subsidiary hoppers in two rows of 18, each row above a railway line. They are designed so that when a train is at rest in the loading position beneath them, two hoppers, with a total content of 56 tons, are over each of the special wagons. When a row of 18 hoppers is filled a complete train load of ore (504 tons), which has been accurately weighed, is held pending the arrival of one of the trains from Consett. On arrival the train is shunted under the subsidiary hoppers which are then simultaneously emptied in less than a minute, and the train without further attention is ready to leave for Consett. Discharge of the train at Consett is equally rapid.

The quay and plant commenced operation on November 23rd, 1953, and the average throughput so far is about 100,000 tons per month. The best performance at the quay appears to be the discharge of the *Pajala* on June 21st–22nd, 1954. The vessel had a cargo of 15,300 tons of ore, and discharge commenced at 6 a.m. on June 21st and was completed at 12.50 p.m. the following day.

The Jarrow Works

In addition to the main works at Consett, the Company owns a modern merchant bar and strip mill and a modern refractory brickworks, both located at Jarrow, on a site formerly occupied by Palmers Iron and Steel Works. The mill, which commenced operations in 1940, is designed to ensure continuity from the billet bank to the loading sidings on the straight line principle. The billets, which are transported from the Consett Works on a shuttle service, are 30 ft. long and from 2 in. up to 4 in. square. The stock also includes slabs of various sizes. The billets are fed to a live roller table, which delivers them to a Morgan standard continuous type furnace. This furnace, which is 35 ft. by 40 ft., has an output of 40 tons/hr. From the hearth of the furnace the billet is fed to the roughing mill, which consists of seven stands, Nos. 0 to 6, together with three edging mills positioned

between Nos. 2 and 3 stands, Nos. 4 and 5 stands, and on the outlet side of No. 6 stand. From the roughing mill the bar runs out on to a skew Y table, whose rolls are running in the direction of the bar. When the bar leaves the roughing mill the rolls are reversed and the bar is fed into the intermediate stand. By the same means of reversal the bar is delivered to the finishing stand. From the finishing stand the bar runs out on to a double-sided cooling bank of the rack carry-over type, from whence it is transferred by means of shuttle bars on to rollers which feed the shears.

The refractory brickworks at Jarrow have been in operation less than two years. Prior to 1952 the silica and basic refractories activities of the Company were concentrated at Templetown, within a mile of the steelworks at Consett, the capacity of the basic plant being 100 tons/week. With the increasing demand for both products it became necessary to separate the activities, and the basic section was removed and incorporated in a new, larger capacity, self-contained factory built alongside the Company's merchant bar and strip mill at Jarrow.

As planned, this factory is divided into four main sections: raw material handling and preparation; blending and mixing; pressing and moulding; and drying and firing. The whole of these, with the exception of the primary crusher and conveyor, are housed in the one building. The raw materials used include magnesite, chrome ore, sillimanite, and andalusite, and the products comprise bricks, shapes and cements, chiefly in magnesite, chrome and chrome-magnesite, up to a weekly capacity of 350 tons. Bricks and the smaller shapes are pressed, while the larger and more awkward shapes are made by mechanical or pneumatic tamping.

The raw materials are fed to a hopper beneath which a steel apron feeder controls the rate of flow to a double-toggle steel-framed jaw crusher. Conveyor belts deliver the crushed material into any one of ten 120-tons capacity raw material bunkers. Under these bunkers is a travelling electro-vibratory feeder, which regulates the flow of material by belt conveyors to a secondary crusher. A continuous bucket-and-belt type elevator raises material from crusher to screen, while products through the screen are conveyed by spiral conveyors to appropriate compartments of a range of fine-materials bunkers having a total capacity of 250 tons. A proportion of the material is subsequently passed through a ball mill —equipped with electro-vibratory feeder, fan, separator, overhead cyclone and valve—from which the fines fall into appropriate bunkers.

Blending is effected by drawing materials in required proportions from the bunkers by means of a batch weigher, arranged to deliver to any one of a group of batch mixers or to two dry cement mixers. Sulphite lye mixing and measuring apparatus is provided in duplicate to serve the batch mixers. Mixed batches are discharged from a centre door, the batch falling down a non-spill chute into a bottom-discharge skip, the latter being arranged to travel along a track, supported from the roof of the press bay, to serve a range of presses.

Three presses and one tamping machine are installed and operating, but there is provision in the layout for each machine to be duplicated. One press is a Fielding and Platt hydraulic 800-tons capacity machine, with downstroke pressing and upstroke ejection, which has push-button control, and may be under manual control for each operation or entirely automatic. A second 800-tons capacity hydraulic press was originally at the Templetown works; this machine operates with upstroke pressing and ejection, mould boxes being arranged in a rotating table and the cycle of operations may either be manual or wholly automatic. The third press is a mechanical one by Whittaker and Co., Ltd., and is entirely automatic in operation.

Bricks and shapes produced by the presses are set on cars of two types, depending upon whether they are to pass through the tunnel dryer and tunnel kiln in sequence, or through the tunnel dryer only. The tunnel dryer, which works in conjunction with the kiln, is 68 ft. long, holds ten effective cars and operates on a pushing cycle of 1·82 hours, resulting in a drying time of 18 hours and a capacity of 175 tons per week. The tunnel kiln is 225 ft. long, taking 36 cars and operating on a time cycle of 1·82 hours per car, resulting in a capacity of 175 tons per week. There are preheating, firing, and cooling zones, and the temperature in the firing zone may be as high as 1,650° C. The larger shapes are set in a batch kiln, 15 ft. 6 in. wide, 40 ft. 9 in. long, and 8 ft. 9 in. deep, which holds 100 tons of material. This kiln is operated on a 14-day cycle, giving an output of 50 tons per week.

There can be no doubt that the large expenditure involved in this reconstruction and expansion of the Consett Works will be more than justified not only in maintaining but in increasing the reputation of this old established Company. Certainly the developments provide a sound basis for the term "architects of productivity," which was applied to the iron and steel engineers during the meeting.

Meeting Diary

Continued from page 206

13th December

Institution of Production Engineers (Sheffield Section). "Welding in the Atomic Energy Projects," by I. H. Hogg. Joint Meeting with the Institute of Welding. The Grand Hotel, Sheffield. 6.30 p.m.

14th December

Society of Instrument Technology. "Atomic Energy Plant Instrumentation," by R. K. Sandiford and V. Koller. College of Technology, Manchester. 7.30 p.m.

15th December

Society of Chemical Industry—Corrosion Group. "Corrosion Prevention in the Telecommunications Industry," by C. E. Richards. Chemical Society, Burlington House, Piccadilly, London, W.1. 6.30 p.m.

16th December

Institute of Metals, London Local Section. "Melting and Casting under Reduced Pressure," by Dr. H. H. Scholefield. 4, Grosvenor Gardens, London, S.W.1. 6.30 p.m.

Liverpool Metallurgical Society. Joint Meeting with the Institute of Welding. "The Use of Protective Atmospheres during the Heat-Treatment of Steels," by Dr. I. Jenkins. The Temple, Dale Street, Liverpool. 7 p.m.

17th December

Institution of Mechanical Engineers. Thomas Hawksley Lecture. "Recent Studies of Metallic Friction," by Dr. F. P. Bowden. 1 Birdcage Walk, Westminster, London, S.W.1. 5.30 p.m.

North East Metallurgical Society. "Some Aspects of Iron Production," by Dr. P. K. Gledhill. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

West of Scotland Iron & Steel Institute. "Non Destructive Testing of Metals," by J. M. Mowat. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

Diffusion of Hydrogen in Titanium*

By R. J. Wasilewski † and G. L. Kehl ‡

This paper describes the investigation of hydrogen diffusion in alpha *and* beta *titanium and observations on the reaction rates incidental to the diffusion work. A simplified method for the vacuum extraction analysis of hydrogen in high-purity titanium is briefly outlined.*

A KNOWLEDGE of the behaviour of titanium in a gaseous environment is of considerable importance in assessing the potential possibilities of the metal as a structural material. It was therefore thought desirable to investigate the diffusion rates of the gaseous interstitial solutes in massive titanium. The present paper describes the investigation of hydrogen diffusion in *alpha* and *beta* titanium and observations on the reaction rates incidental to the diffusion work.

No data on hydrogen diffusion were obtainable from previous accounts[1, 2] of work on titanium reactions with hydrogen. The data available indicated only that the condition of the metal surface might affect the reaction rates to a considerable extent, and that the overall rates were likely to be very high at temperatures above approximately 350° C. The equilibrium diagram of the binary titanium-hydrogen system[3] shows that the absorption of hydrogen lowers the transition temperature, stabilising the body-centred-cubic *beta* structure, and that the solid solubility of the gas in the *alpha* phase is fairly limited, with a maximum of 7·9 at.-% at 320° C. At the same temperature a eutectoid decomposition of *beta* into *alpha* and *gamma* takes place at 38 at.-% hydrogen.

Since the *gamma* (hydride) phase does not form above 640° C. at atmospheric pressure of hydrogen, the absorption of hydrogen by titanium above the transformation temperature of the pure metal (882·5° C.) could be expected to result in simple homogeneous diffusion of the solute into the *beta* structure. Furthermore, if a quantity of hydrogen sufficient to stabilise the *beta* structure at a lower temperature is introduced into the metal prior to the diffusion experiment, any further gas addition at this temperature may again be expected to result in homogeneous diffusion. In the case of hydrogen absorption by the metal originally in the *alpha* form, however, it is likely that the surface would transform, and that the surface layer of the *beta* phase formed would grow in thickness with continuing absorption. A further complication is introduced at temperatures below 640° C., when the hydride formation takes place. An approximate determination of the diffusion coefficients is possible, provided these surface layers are thin.[4] It was thought improbable, however, that the thickness of the *beta* layer would be small as compared with the solute penetration into the *alpha* core, in view of the fact that more rapid diffusion rates are likely in the relatively open *beta*, than in the close-packed *alpha* phase. Therefore, it was necessary to investigate experimentally the effect of the formation of both the *beta* and the hydride surface layers before devising a suitable procedure for the investigation of diffusion in *alpha* titanium.

TABLE I.—THE ANALYSIS OF THE TITANIUM BASE METAL BEFORE AND AFTER PROCESSING.

Element	Mean of Lot Analyses of Crystal Bar* (wt.-%)	Duplicate Analyses after Processing† (wt.-%)	
N	0·005	0·004	0·001
H	Not determined	0·0069	0·0068
		0·0063‡	0·0062‡
O	Not determined	0·011‡	0·010‡
C	Not determined	0·034	0·038
Mn	0·007	0·03	0·03
Fe	$0{\cdot}010_5$	0·005	0·005
Al	$0{\cdot}013_4$	0·01	0·01
Cu	0·007	0·001	0·001
Mg	$0{\cdot}001_5$	0·005	0·005
Mo	0·003	Not detected	
Pb	0·006	Not detected	
Sn	$0{\cdot}001_4$	Not detected	

Not detected: Zn, Ag, Be, V, P, Zr, Bi, B, Cd, Sb, As, and La. The hydrogen and oxygen analyses were carried out by vacuum fusion methods, chemical analysis was used for carbon and nitrogen, and all the other impurities were determined spectroscopically.

* Analysis supplied by Watertown Arsenal.
† Analyses by Battelle Memorial Institute on swaged rod, except as noted by (‡).
‡ Vacuum fusion analyses at Columbia University, after machining to 0·350 in. diameter.

General Method

Iodide titanium obtained from Watertown Arsenal was used throughout this work. Since the as-deposited metal is too porous to permit direct specimen use, the crystal bar deposit was arc-melted under argon*, using a water-cooled copper crucible. The button was then hot-forged at 700° C., rolled at 650° C. to ½ in. rod, pickled in a conventional HNO_3-HF solution, and finally swaged cold to ⅜ in. diameter rod. The cylindrical and disc specimens used were machined by turning this rod down to 0·350 in. diameter. These operations, when carried out carefully, cause negligible contamination of the metal[5], and this can readily be checked by the hardness change. The hardness of the swaged rod, as vacuum annealed for one hour at 750° C., varied between 58 and 64 D.P.N. (10 kg. load), compared with 55 to 63 D.P.N. (converted from Brinell hardness measurements) of the as-cast button. The chemical analysis of the specimen metal is shown in Table I.

The hydrogen used was obtained from uranium hydride, formed by saturating 200 g. of uranium with cylinder hydrogen at 250° C. The quartz tube containing the hydride was connected directly to the Sieverts' gas addition apparatus, and whenever the

* This paper is based on part of the thesis by R. J. Wasilewski submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in the Faculty of Pure Science, Columbia University, New York.

† Edibrac, Ltd., formerly graduate student, Columbia University, New York.

‡ School of Mines, Columbia University, New York.

* The melting and working operations were performed at Battelle Memorial Institute, through the courtesy of Mr. H. Saller.

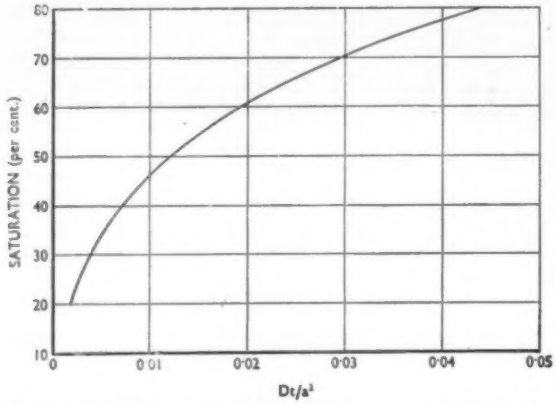


Fig. 1.—Relative saturation *v.* the parameter Dt/a^2 for diffusion into discs of 3 : 1 diameter : thickness ratio, where a = disc radius.

hydrogen was required the tube was heated to 445° C. and the necessary quantity of the gas drawn into the gas burette. This hydrogen source was found to be extremely convenient in operation. Metal-gas reactions were carried out in a Vycor (96% silica) glass reaction vessel, which could be evacuated by means of a two-stage mercury diffusion pump, and maintained under vacuum at temperatures up to 1,000° C. The reaction temperatures were measured by means of calibrated Chromel/Alumel thermocouples, and maintained within ± 2° C. throughout each diffusion run. Since the reaction rates were followed in some cases, the effective reaction volume was measured with argon purified by passing it through titanium chips at 950° C. The amount of the gas admitted could be read to 0·1 ml. at room temperature and pressure, and varied between 40 and 80 ml., depending on the tube used.

It was considered necessary to ensure reproducible reaction conditions, particularly as regards the metal surface. Consequently, each specimen was first abraded under pure kerosene on silicon carbide papers down to No. 600, washed with water and detergent, then washed again in acetone and immediately inserted into the reaction vessel, which was then evacuated. In order to remove the effects of cold working to a comparable extent in all the specimens, they were annealed *in vacuo* for one hour at 1,000° C. after this initial preparation. The reaction vessel was then cooled to the temperature required, and the diffusion run started after this temperature had been maintained constant for a minimum of 30 minutes. This treatment was considered sufficient to ensure the solution of any superficial oxide films present on the specimen surface.

Hydrogen Diffusion in Beta Titanium

Experimental Method.

The high diffusion rates expected, and the high solubility of hydrogen in *beta* titanium structure (between 70 and 230 ml. S.T.P. per gram, depending on temperature), indicated that the preparation of diffusion specimens and the subsequent determination of the concentration gradient obtained would not be feasible. It seemed appropriate, therefore, to use the integrated form of the solution of the diffusion equation, thereby making it possible to calculate the diffusion coefficient at a given temperature from the experimental determination of the time necessary to reach a known value of the relative saturation in the diffusion specimen. The computed values of the integrated solutions of Fick's diffusion equation, with the diffusion coefficient assumed constant, have been given by Newman[6] for a semi-infinite slab, an infinite cylinder, and a sphere. From these, corresponding calculations can be made for a number of simple, finite shapes. Computations have been carried out to determine the relationship between the relative saturation and the value of the parameter Dt/a^2 for a disc having a diameter to thickness ratio of 3 to 1. This relationship is shown graphically in Fig. 1, where the parameter Dt/a^2 is given in terms of the disc radius a. In conformity to the ratio of 3 to 1, specimens were machined to 8·90 mm. diameter and 2·97 mm. thick. The volume of hydrogen corresponding to maximum saturation was determined from the known solubility data and the weight of the specimen.

It is easily seen from Fig. 1 that the most accurate measurements of absorption against time can be made for saturation values between 0·45 and 0·70. It was therefore decided to take a number of readings of volume absorbed against time during every diffusion run

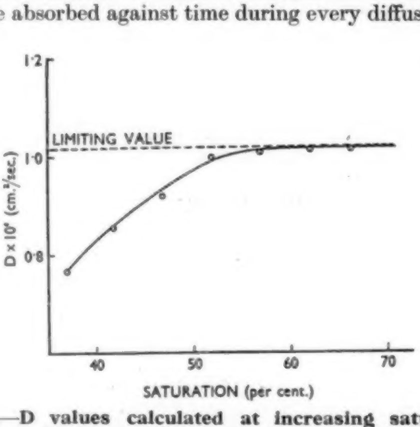


Fig. 2.—D values calculated at increasing saturation in hydrogen diffusion in beta titanium.

within this intermediate saturation range. The diffusion coefficient values corresponding to every pair of readings could then be determined by simple calculation. The gas burettes used were designed specifically to facilitate rapid initial addition of the gas, and an accurate determination of the volume admitted within the required saturation range. To ensure that the *beta* structure was retained in the specimens investigated below the transformation temperature, a known quantity of hydrogen was admitted immediately after the anneal, at 1,000° C., just sufficient to prevent the formation of the *alpha* phase at the diffusion temperature of interest. The specimen was then maintained at 1,000 °C. for a further 40 minutes, to ensure homogeneous solute distribution. The diffusion run proper was carried out by admitting hydrogen to the known reaction volume and maintaining atmospheric pressure in this volume by raising the mercury level in the gas burette. The readings of the volume absorbed against time were taken, and subsequently converted to standard temperature and pressure.

In view of the fact that finite time (about 2–6 seconds, depending on the temperature) was required for atmospheric pressure to be attained in the reaction volume, the values of the diffusion coefficient as calculated from

the time readings for lower saturation values tended to be low. The typical variation of the values calculated in this way is shown in Fig. 2, plotted from the data obtained at 900 °C. As can be seen, with increasing degree of saturation, i.e., time of reaction, the calculated coefficient values approach a limiting value. The limiting diffusion coefficient thus obtained was taken as the true diffusion coefficient.

Experimental Results.

The diffusion coefficient of hydrogen in *beta* titanium was found to vary between $1 \cdot 1 \times 10^{-4}$ cm.²/sec. at 1,000° C., and $0 \cdot 52 \times 10^{-4}$ cm.²/sec. at 650° C. From the plot of log D against reciprocal temperature shown in Fig. 3, the equation

$$D_\beta = 1 \cdot 95 \times 10^{-3} \exp. \left(- \frac{6{,}640 \pm 500}{RT} \right)$$

was obtained by the method of least squares.

A single run carried out at 600° C. and 200 mm. Hg hydrogen pressure, under which conditions no formation of the hydride takes place, gave a value for D_β in agreement with the above equation. This is shown by the corresponding point in Fig. 3.

Since the applicability of the method of mathematical analysis chosen depends on the constancy of the diffusion coefficient, this was checked at 650, 750 and 900° C. In each case this check was carried out by determining the time necessary for 50% saturation, using three specimens with initial hydrogen content varying from 0 to 60% saturation. The variation obtained was well within the experimental accuracy, estimated at ± 10%, as shown in Table II.

Discussion of Results.

From the experimental data obtained, it appears that in spite of the extensive solubility range of hydrogen in this titanium structure, no marked variation of the diffusion coefficient is likely to exist throughout most of the concentration range investigated. However, the initially low diffusion coefficient values shown in Fig. 2, while at least in part due to the finite time required for the atmospheric pressure to build up in the reaction volume, may also in part be due to the diffusion coefficient being significantly concentration-dependent

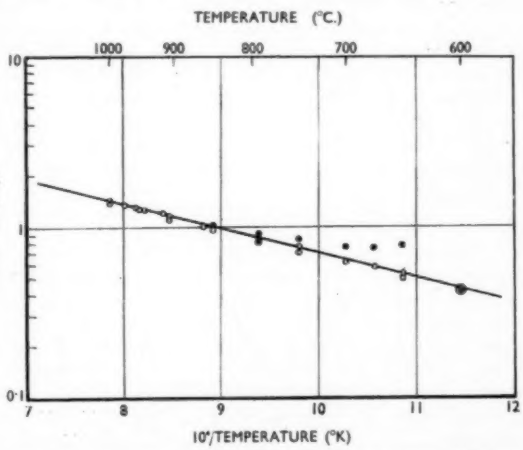


Fig. 3.—Temperature dependence of hydrogen diffusion in beta titanium. The circles represent values of D_β at 760 mm.; the concentric circles D_β at 200 mm.; and the solid circles the apparent D for the alpha-beta reaction.

TABLE II.—DIFFUSION COEFFICIENTS OF HYDROGEN IN *BETA* TITANIUM AT VARYING INITIAL SOLUTE CONCENTRATION

Diffusion Temperature (° C.)	Saturation %		Time Required (sec.)	D (cm². sec. × 10⁴)
	Initial	Final		
900	0	50	21	1·11
	24	62	22·3	1·05
	58	79	21·6	1·08
750	0	50	30	0·78
	27	64	33	0·71
	60	80	31·6	0·74
650	0	50	46	0·506
	32	66	44	0·53
	54	77	44·6	0·52

at very low hydrogen concentrations. The measurement of the time required for the absorption of small quantities of gas was subject to a large error, since at all temperatures it took a maximum of only a few seconds to reach even 10% saturation—a relatively high value. It was, therefore, impossible to determine a variation in the diffusion coefficient at these low saturation values, should it exist. However, while it must be stressed that, on the basis of the data obtained in this work, the possibility cannot be excluded of a marked variation in the diffusion coefficient at low hydrogen concentrations, which correspond to very low external pressures of the gas, or very short diffusion times, the values obtained can otherwise be considered representative of the behaviour of hydrogen in *beta* titanium.

Hydrogen Diffusion in Alpha Titanium

Exploratory Investigations.

When using titanium specimens originally in the *alpha* form, the hydrogen pressure must be of the order of 4 mm. Hg., or less, in order to ensure homogeneous diffusion without the formation of new phases. Making diffusion runs at this pressure, and determining the diffusion coefficients in the way previously described, would necessitate a large and complex gas addition apparatus. In order, therefore, to obtain data for a simpler experimental method, the formation of the new phases during titanium reactions with hydrogen was investigated under varying conditions.

(*a*) *Alpha-Beta Transformation.*

The reactions within the *alpha-beta* range were carried out by admitting the gas into the reaction vessel with the specimen initially in the *alpha* form, at temperatures between 650° C. and 860° C. It was found that the reactions in this temperature range were more rapid than those with *beta* titanium at corresponding temperatures. In order to present this difference, the results were converted into apparent D values by the method used in the investigation of diffusion in *beta* titanium. The results thus obtained are shown in Fig. 3.

It is believed that the apparently increased reaction rates in this range are due to the effects of the *alpha* to *beta* transformation at the gas-metal interface. The presence of the *beta* phase formed during the reaction cannot in itself account for the increase of the apparent D values, since the values observed lie above those of D_β for corresponding temperatures. Therefore, it is suggested that the transformation may result in the formation of small, discrete blocks of the *beta* phase rather than a continuous layer, and hence introduce a number of microcracks in the specimen's surface. Owing to the rapid diffusion rates of hydrogen in *beta* titanium, and the small dimensions of the *beta* blocks formed, the saturation of these would be almost

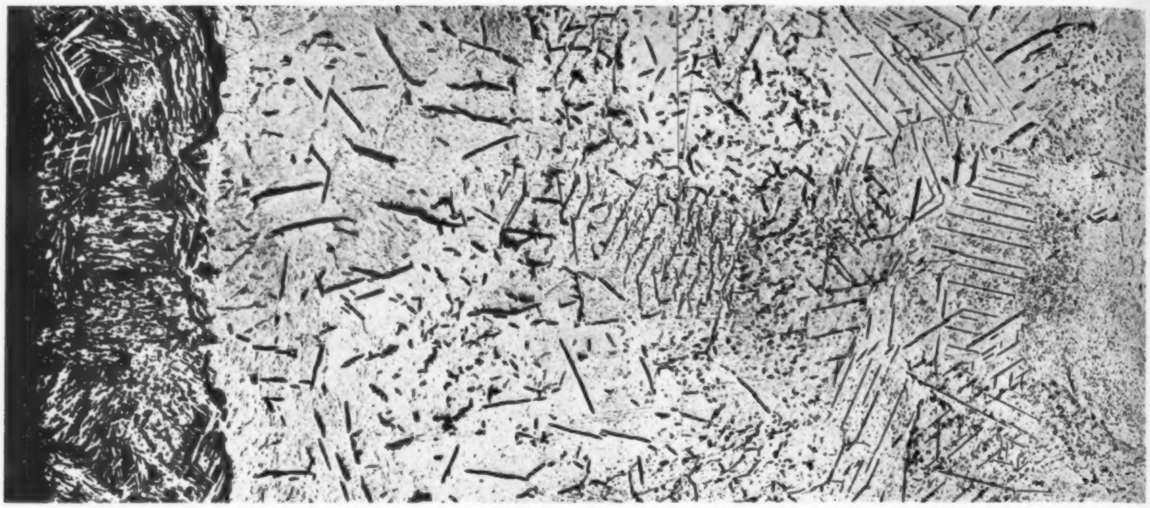


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Fig. 4.—Transformed beta surface layer and hydrogen concentration gradient obtained in 20 minutes at 550° C. after admission of 100 ml. hydrogen. Air Cooled. Etched 3 : 1 : 1 glycerol : HNO_3 : HF. × 100

instantaneous. The effect of such a process would be effectively to decrease the characteristic dimension a in the parameter Dt/a^2, hence the diffusion coefficient as calculated on the basis of the original geometrical dimensions of the specimen would tend to be high. The overall reaction rates would in this case be controlled by the rate of transformation and/or the dimensions of the *beta* blocks formed.

(*b*) *Beta-Gamma Reaction.*

The reactions between *beta* titanium and hydrogen to form the hydride were briefly investigated throughout the temperature range 625–330° C., at intervals of approximately 30° C. The quantity of hydrogen necessary for the saturation of the *beta* phase, at the reaction temperature desired, was admitted to the reaction vessel towards the end of the preliminary anneal at 1,000° C., and the specimen then cooled to the reaction temperature selected within approximately two hours. This relatively long cooling period was considered necessary to ensure full absorption of the gas, and its homogeneous distribution throughout the specimen. Because of the amount of hydrogen thus absorbed, the specimens were initially in the fully saturated *beta* condition, and any further hydrogen absorption could take place only by the formation of the hydride.

In all the experiments an initially linear reaction rate was observed. After a degree of absorption corresponding to about 65–75% of the maximum possible was reached, the rate began to decrease. The reactions were not followed to higher saturation values.

At atmospheric hydrogen pressure the linear reaction rates increase sharply with a decrease in temperature from 625° C., and show a maximum at about 500° C. Further decrease in temperature lowers the rates rapidly, and the rate is just measurable at 330° C. The rates vary from approximately 0·0025 ml. S.T.P./cm.^{2}/sec. at 625° C. to 0·011 at 500° C. and 0·00006 at 330° C. Because of the difference in density between the *beta* and *gamma* phases[1] the absorption results in a considerable enlargement of the specimens. The hydride formed is brittle, and can be readily rubbed off.

The general variation of the reaction rates with temperature is similar to that for any chemical reaction. At equilibrium, i.e., atmospheric pressure and 640° C.,[3] no reaction takes place, the saturated *beta* existing in equilibrium with the hydride. As the temperature is lowered, pressure remaining constant, the effect of the departure from the equilibrium conditions is initially to increase the reaction rates. As the temperature is further lowered beyond the optimum value, the resultant decrease of the rate becomes more rapid than the increase due to the further departure from the equilibrium pressure, and the overall reaction rate falls rapidly.

The linear rates observed indicate that no continuous layer of the hydride is formed during the reaction. In view of the considerable difference between the density of the hydride and that of titanium metal, it is believed likely that the compressive stresses set up in the initially formed hydride film are high enough to break all but the thinnest films of the brittle hydride, and that, in consequence, fresh *beta* surface is constantly exposed to the gas. The reaction would in this case be controlled by the amount of the metal-gas interface present, and this remains substantially unchanged until a late stage of the reaction.

(*c*) *Alpha-Beta-Gamma Reactions.*

This investigation was carried out at atmospheric pressure through the temperature range 625–330° C., with no initial hydrogen addition. It was expected that upon the addition of hydrogen the transformation of the surface to the *beta* phase, and the later formation of the hydride might be indicated by discontinuities in the overall plot of the reaction rates. It was found, however, that the reaction rates did not obey any simple rate law. In general, the rates were initially low, but increased rapidly after an incubation period of varying length, specially marked at low temperatures. Qualitatively, the overall reaction rates observed between 625° C. and 550° C. were more rapid, and between

520° C. and 400° C. slower than those for the *beta-gamma* reactions at corresponding temperatures. The reactions were extremely slow below 400° C., and no reaction was detected at 350° C. and 330° C.

The low initial rates observed are probably attributable to the contamination of the metal surface. The rate appears to be particularly sensitive to the presence of oxide on the specimen surface, and the persistence of the low reaction rates is a function of the degree of surface oxidation. It was experimentally demonstrated that by oxidising artificially part of the specimen surface, the reaction at 620° C. was effectively limited to the remaining unoxidised part of the surface for a period of at least three hours, during which observations were made. The persistence of the low rates may thus be associated, either with the presence of an oxide film, or with the hindrance of the *alpha* to *beta* transformation, arising from the influence of oxygen in stabilising the *alpha* structure. The accelerated later rate is probably controlled by the gradual *alpha* to *beta* transformation, as previously mentioned.

Experimental Method.

The method used consisted of the preparation of diffusion specimens, experimental determination of the hydrogen concentration gradient, and the mathematical analysis of the data thus obtained, based on the solution of Fick's diffusion equation for diffusion into an infinite cylinder, as described recently by Mallett *et al.*[4] Cylindrical specimens 45 mm. long and 9 mm. diameter were used. After the diffusion run, two lengths of approximately 6mm. each were cut off each end to eliminate the end effects. The remaining length had a solute concentration gradient due solely to radial diffusion, provided the diffusion time was such that Dt/a^2 was less than 0·04. This length served for the preparation of analytical samples for the determination of the radial concentration distribution. Both the diffusion coefficient value, and the maximum (surface) solute concentration could then be determined from the experimental data.

This mathematical analysis method does not take into account the formation of the surface layer of saturated *beta* phase, as homogeneous diffusion is assumed. The error involved in neglecting this layer formation is, however, small, provided the thickness of the layer is small compared with the radius of the specimen. To prevent the formation of excessively thick layers of the transformed *beta*, the quantity of hydrogen admitted into the reaction vessel at the beginning of the diffusion run was that calculated to result in the formation of a *beta* layer 80–120 microns thick. This amount of gas was rapidly absorbed, and the pressure in the reaction volume fell to a few millimetres. It was assumed that the *alpha-beta* interface would, in effect, provide a constant hydrogen concentration at the surface of the *alpha* core, equivalent to that obtained by having the *alpha* phase in a hydrogen atmosphere at equilibrium pressure.

Since at temperatures below 600° C. a tendency towards non-uniform reaction was observed, some specimens forming the *beta* phase over only part of their surfaces, all the specimens were checked for the thickness and uniformity of the *beta* layer by microscopic examination of the two end sections. Only specimens found to be satisfactory in that respect were analysed for the radial hydrogen distribution. The maximum thickness permitted was 150 microns (∽ 3% of the original radius).

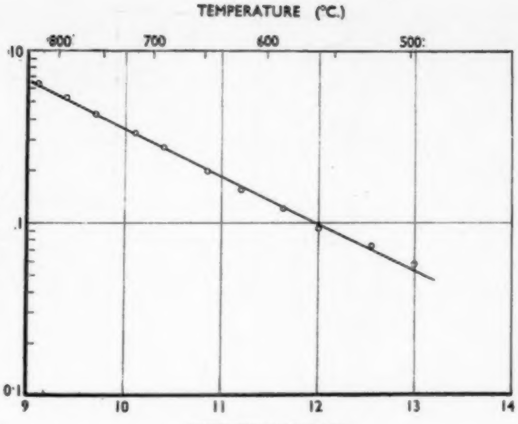

Fig. 5.—Temperature dependence of hydrogen diffusion in alpha titanium.

The uniformity of the thickness of the surface layer, and the illustration of the concentration gradient within the core are shown in Fig 4.

A method of preparation of seven to eight small (250 mg.) chunk samples from the diffusion specimens was devised, as using chips was found cumbersome and unreliable. The *beta* surface layer was removed prior to the preparation of these samples. The analyses were carried out in a standard vacuum fusion apparatus, essentially as described by Guldner and Beach.[7] The conventional analysis methods recommended require a temperature of 1,650° C., and either the use of an iron bath,[8] or the addition of tin[9] to the sample. Since the data on the diffusion of hydrogen in *beta* titanium indicated that quantitative evolution of the gas *in vacuo* should take place within 2 minutes at 1,200° C. for the shapes of the samples used, the analyses were run at 1,200° C. rising to 1,400° C. in 20 minutes, with no tin addition. Check analyses by the above method, and by the tin addition method recommended by the makers, showed excellent agreement. The lower temperature used resulted in a considerable saving of time necessary for the initial outgassing of the apparatus. It must be stressed, however, that only low oxygen samples were analysed. The evolution of hydrogen from titanium containing an appreciable amount of oxygen may well be much slower, and a more elaborate analytical procedure may be necessary for such samples.

Experimental Results.

The temperature variation of the hydrogen diffusion coefficients in *alpha* titanium is shown in Fig. 5. From the data obtained between 500° C. and 824° C., the following equation has been obtained by the method of least squares :

$$D_\alpha = 1\cdot 8 \times 10^{-2} \exp.\left(-\frac{12{,}380 \pm 680}{RT}\right)$$

In all the cases examined, the agreement between the experimentally determined radial concentration gradient and the theoretical curve of best fit was well within the estimated accuracy of the hydrogen analysis (5%). A typical curve showing the experimentally determined concentration gradient, and the nearest theoretical curve of best fit is shown in Fig. 6. The accepted parameter value for this specimen was $Dt/a^2 = 0\cdot 058$. In most cases, however, the *alpha* phase adjacent to

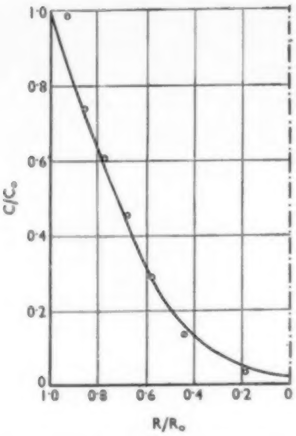

Fig. 6.—Typical radial hydrogen concentration gradient in alpha diffusion specimen. The circles represent experimental data on specimen H50 at 688° C. for 7 minutes, whilst the curve is calculated from $Dt/a^2 = 0 \cdot 06$. C_0 is the concentration at the surface and R_0 the radius of the specimen.

the surface layer of *beta* showed a concentration higher than that theoretically indicated. In two cases this was due to the *beta* layer having been slightly thicker than the surface layer removed prior to the analysis. Other possible reasons for this discrepancy will be discussed below.

Discussion of Results.

The interstitial space, assuming the metal atoms to be rigid spheres, amounts to approximately 32% of the total volume in the body-centred-cubic lattice (*beta* titanium), 25·67% in an ideal hexagonal close-packed lattice, and 26·5% in the *alpha* titanium lattice, which is nearly hexagonal close-packed. The interstitial positions in the *beta* structure are all of the tetrahedral type, with a radius of 0·44 Å. The *alpha* structure, however, possesses two types of interstitial positions, the tetrahedral, of radius equal to 0·343 Å, and octahedral, of radius 0·62 Å.[10] The influence of the dissolved hydrogen in stabilising the *beta* structure can be readily explained in view of these geometrical relationships, if the approximate value of 0·41 Å[11] is accepted for the radius of the hydrogen atom. The tetrahedral positions in the *alpha* titanium structure are too small to accommodate the solute atom. Some limited solution might be possible by siting the solute in these positions, but it would then be expected to be accompanied by considerable lattice distortion. This; however, is not likely to be the case, in view of the relatively slight effect on the hardness and lattice parameter resulting from small hydrogen additions. It is, therefore, believed that the solute atoms are accommodated in the octahedral positions, and the transformation to *beta* is caused by the high free energy due to the freedom of vibration in these positions.

Diffusion in the close-packed hexagonal *alpha* phase being slower, and its activation energy higher, than the diffusion and activation energy in the *beta* phase at corresponding temperatures, are readily explained on the same basis. These effects are to be expected, in view of the decreased interstitial space, and the increased number of nearest neighbours for an interstitial position in the *alpha*, as compared with the *beta*, structure.

The lack of agreement between the theoretical and experimental values for the solute concentration in the *alpha* phase adjacent to the *beta* layer, corresponding to the relative radius value of approximately 0·94, may well be significant. It is possible that this high solute concentration was caused by some diffusion taking place during the quenching of the specimen after the diffusion run, as the hydrogen solubility in the *alpha* phase increases with temperature decrease down to about 575° C. In this case, however, no discrepancy should have been observed in specimens reacted at lower temperature, and yet all the specimens examined showed it. A concentration-dependent variation in the diffusion coefficient, however, would be expected to increase D_a at higher hydrogen concentrations. If this were the case, the concentration gradient at these higher solute concentrations would be smaller than that indicated by the theoretical curves. The experimental values would then show a flattening of the corresponding curve as the value of the relative radius approaches unity. In consequence, the layers corresponding to higher relative radius values, possessing a concentration gradient lower than that given by the theoretical curves, would analyse the hydrogen concentration as higher than that predicted by the mathematical solution used.

It is, therefore, concluded the the possibility exists of the diffusion coefficient varying with solute concentration at higher concentration values. In view, however, of the otherwise good agreement between the experimental data and the values calculated on the assumption of constant diffusion coefficient, the variation of D_a must be small throughout most of the concentration range investigated, i.e., between 0 and 7·9 at.-% hydrogen. The diffusion coefficient may possibly vary markedly with the solute concentration within a limited range of high solute concentration, probably above at least 5 at.-% hydrogen.

Acknowledgment

One of the authors (R.J.W.) is indebted to the Mutual Security Agency for the award of a fellowship which made the preparation for this work possible. The research described was carried out at Columbia University and sponsored by Watertown Arsenal, under contract No. DA-30-069-ORD-644. Miss Rhea Plottell carried out some of the vacuum fusion analyses.

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Henry Bessemer

An Inventive Genius of the Nineteenth Century

By Eric N. Simons

Although the name of Bessemer is usually associated with the process he devised for the production of steel from molten pig iron, this was only one of the many directions in which he turned his inventive genius. His interests ranged from printing to glass making, from continuous casting to lead pencils, and from gun-making to a means of preventing sea-sickness. It is therefore impossible in a brief article such as this to do more than make passing reference to a few of his achievements.

Sir Henry Bessemer in his eightieth year.

FEW figures in metallurgical history are of greater interest than Sir Henry Bessemer, a man of extraordinarily fertile invention, who took up no subject without bringing to it a fresh and inventive mind, so that if he did not revolutionise it, he did at all events bring about improvements in numerous directions. In the present article one can but briefly enumerate the main events and achievements of a full and fruitful life.

He was born at Charlton, near Hitchin, on 13th January, 1813, the son of Anthony Bessemer, himself an inventor and engineer of some ability, who had erected a factory for making gold chains. Later, in partnership with a former associate, Henry Caslon (a name imperishably attached to a beautiful face of printing type), Anthony set up a type factory, and also went in for die-sinking, turning out very good work.

Early Metallurgical Interest

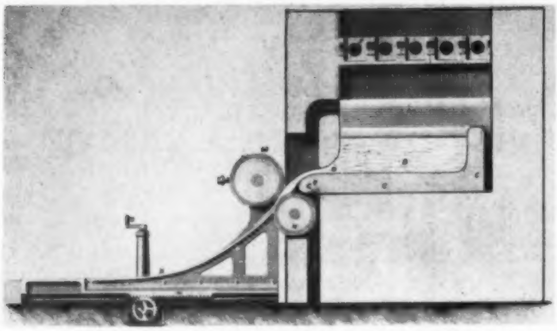
Henry Bessemer received an elementary education, and spent much time in his father's workshop. Village life was quiet, but the periodical melting of type metal at the little foundry was always an interesting event. It was melted in a large furnace, and the procedure was kept secret. Nevertheless, despite parental prohibition, young Bessemer used his brains to discover ways of getting into the melting house, where large masses of antimony were broken up to form the alloy with lead. The dust from the powdered antimony used to make him sick, and this 'gave him away' to his father. He discovered, however, that his father's secret was the addition of tin and copper in small amounts to the normal alloy, and this made the type last much longer than other makes.

In 1830, Anthony Bessemer transferred his business to London. Seventeen years old, the adolescent Henry began to do art work in white metal, and afterwards in copper-coated castings of the same kind: his work was frequently shown at exhibitions organised by the Royal Academy at Somerset House. This work led him to try his hand at the embossing of material, cards and fabrics, for which purpose he used a fly press, later installing a hydraulic press. He has recorded his delight on securing his first order from Ackermann's, the art publishers, for embossed work on buff-coloured cardboard. His impressions cost him 3d., including the material, and he sold them in quantities at 2s. 6d. each.

At that time the British Government was being robbed by the removal of stamps from old and useless parchment deeds, which stamps were again stuck on to new skins of parchment. Bessemer played with the notion of making a stamp non-transferable from deed to deed; more difficult to produce; and incapable of yielding a die that would reproduce the stamp. In the end, he invented perforating dies which fixed the date indelibly on each stamp.

He actually made a die and printed off a few forged stamps. Armed with these he set off to call upon Sir Charles Presley, Vice-President of the Stamp Office, to show how easily the existing stamps could be forged. On the way he bought an orange at a fruiterer's, and while eating it on his way up Fleet Street, found he had left his parcel behind. Had the shopkeeper opened it and handed it to the police, Bessemer would have been arrested. Great was his relief, therefore, when, on dashing back to the shop, he found his parcel untouched.

His invention was eventually adopted, and he was promised a permanent official appointment. The



Bessemer's method of rolling sheet glass.

promise was not kept, however, and he was paid nothing for the service he had rendered. (The Government saved about £100,000 a year).

Lead Pencils

Disappointed, Bessemer turned to other sources of income. Black-lead pencils attracted his attention. Only one plumbago mine suitable for pencil leads existed in Britain, near Borrowdale in Cumberland. Plumbago is found in small nodules, about the shape and size of a potato. These little nodules had in those days to be sawn into slices about $\frac{1}{16}$ in. thick, by hand, the skilled men doing this work being paid a guinea a pound. The difficulty of cutting without breaking was great, and from each 1 lb. of plumbago only about 9 oz. of properly sliced material was usually obtained, the rest being dust or plumbago waste.

Bessemer invented a successful machine for sawing the plumbago and offered to saw for a pencil manufacturer at a nominal cost. The offer was not accepted because, the firm stated, they could not let their secretly-prepared plumbago leave their premises. Disappointed again, Bessemer made use of the plumbago waste, which he bought for 2s. 6d./lb. By cleaning and compressing it into blocks, he was able to cut it up into pencil slips, marketed at 4s. 10d./lb. In the end he sold the invention for £200, though he might have obtained much more.

He now began to cast type under pressure and to make creditable improvements in engine turning. This brought him into contact with Thomas de la Rue, and in 1838 he invented a type-composing machine. This was used at the printing office of the *Family Herald*, where it set 5,000 type an hour. The machine died an unnatural death, however, because it could be worked by female labour, and this was strongly opposed.

Bessemer next perfected a process of making imitation Utrecht velvet, a harsh and stubborn waste material. All previous attempts had failed, but he succeeded in designing the machinery and engraving embossing rolls for the process. He was first paid 6s./yd. for passing the fabric through the rolls, but later the price fell to 1s./yd. Prices still fell, so he sold the machines and stock of engraved rollers to Gillett Lees & Co., Banbury, velvet weavers.

Metal Powder

In 1840, Bessemer began to make bronze powder and gold paint. The powder used at that time was a secret originally held by China and Japan, but German imitators sold their product for 110s./lb. The powder was of various copper alloys beaten into thin leaves, ground by hand to powder on a marble slab with a stone muller, then mixed with a thick solution of gum arabic to form a stiff paste and simplify grinding. Successive washings in hot water removed the gum.

Bessemer failed to produce a similar material at a lower price, but, after microscopic study, he eventually produced mechanically a powder as good as the German product at a much lower price. He would not patent his secret process, but entrusted it to a few relatives and produced the powder in a works of his own. The Germans tried to bribe his chief engineer and craftsman to reveal the secret. Bessemer himself, under the name of 'Mr. Henry,' was taken by the engineer to meet the spy, to whom he gave a fictitious account of the process. The spy took this back to Bavaria, with unknown results.

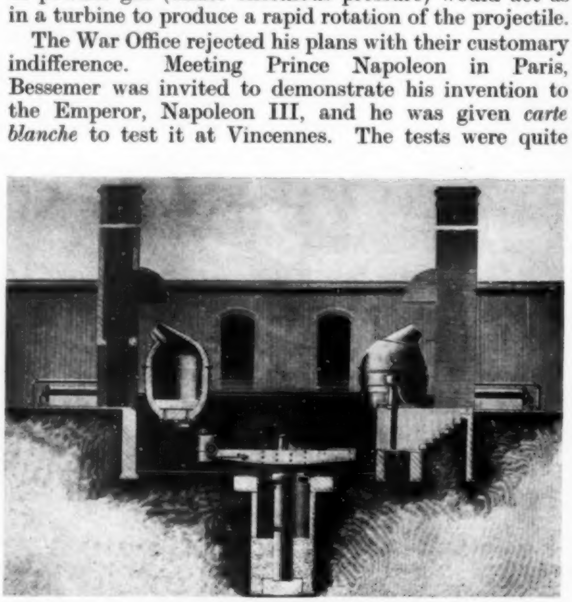
He and his relations successfully kept the secret for about thirty-five years, but when the price had come down to 2s. 6d./lb., the profit declined and the works were given up. Long before this, however, Bessemer had given them to Richard Allen, his brother-in-law. It was with the profit from this process that Bessemer was able to finance his third great invention.

He meantime improved sugar-refining machinery, at no profit to himself, and carried out remarkable improvements in making plate glass. One of his patents was sold to Chance, the glass-maker, for £5,000, but other glass-making inventions, though quite practical, were never taken up.

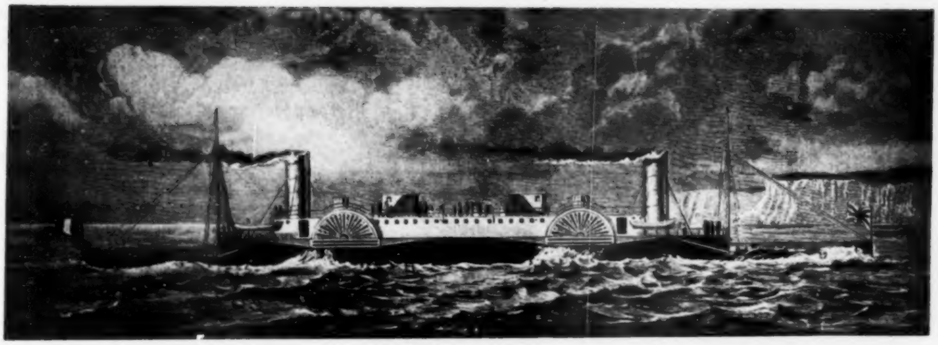
Projectiles

The Crimean war turned his attention to guns, and it occurred to him that a projectile fired from a smooth bore gun might be rotated by letting part of the powder gas escape through longitudinal passages formed in the interior or on the outer surface of the projectile. If such passages terminated in the direction of a tangent to the circumference of the projectile, the tangential emission of powder gas (under enormous pressure) would act as in a turbine to produce a rapid rotation of the projectile.

The War Office rejected his plans with their customary indifference. Meeting Prince Napoleon in Paris, Bessemer was invited to demonstrate his invention to the Emperor, Napoleon III, and he was given *carte blanche* to test it at Vincennes. The tests were quite



Bessemer plant at Sheffield showing converters, ladle, crane and casting pit.



The channel steamer "Bessemer."

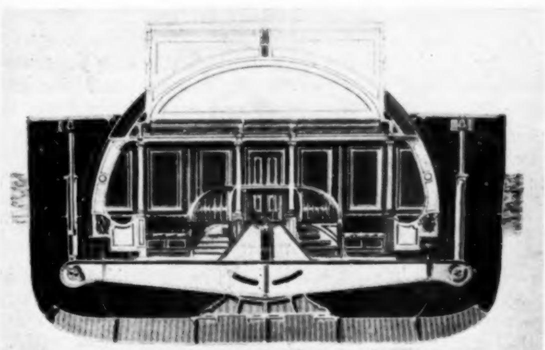
successful, but the French doubted the ability of their guns to withstand such heavy projectiles, and it was this that led to the introduction of the Bessemer process of steel manufacture.

Faced by the task of making a gun strong enough to throw heavy projectiles, Bessemer, who knew nothing about ferrous metallurgy other than what an average engineer of the time might be expected to know, began by trying to make a better cast iron. Three weeks after the gun tests at Vincennes, he patented the production of a combined metal by the fusion of steel in a bath of molten pig iron in a reverberatory furnace.

His first experimental cast iron gun was presented to the Emperor Napoleon, who wished to present him with the Order of the Legion of Honour, but the British Ambassador twice prevented him from accepting this, a fact that rankled for many years. Bessemer's experiments were first carried out in the open-hearth furnace, but his patent for the fusion of steel in a bath of pig iron on the open-hearth of a reverberatory furnace, taken out ten years before the Siemens-Martin patent, did not approach within measurable distance of the commercial open-hearth process.

Steel

While melting pig iron in the reverberatory furnace, however, Bessemer saw some pieces exposed to the air blast on one side of the bath which remained unmelted despite the great heat. They proved to be mere shells of old decarburised iron, the carbon having been burned out by the blast. In October, 1855, he patented a process in which crucibles charged with molten pig iron had air under pressure blown through them. In December of the same year, he patented the running of molten pig iron from the blast furnace or cupola into a large tipping vessel—the Bessemer converter—an air blast being introduced through tuyères to pass through the charge. On the 15th March, 1856, followed a patent for adding recarburising material to a charge from which carbon and impurities had been burned out by the blast, so as to restore a given percentage of carbon according to the quality of steel required. In the summer of 1856 he read his famous paper at the Cheltenham meeting of the British Association.



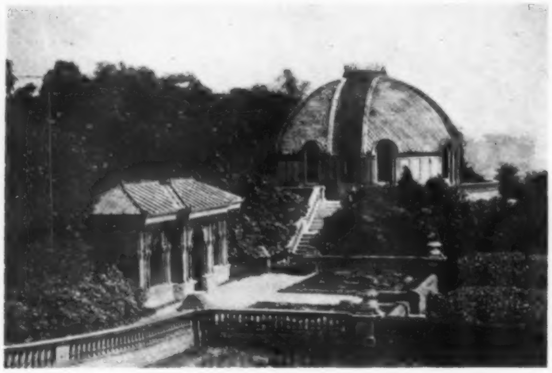
Transverse section of saloon on channel steamer "Bessemer."

The problem he had to solve was how to decarburise the charge completely and keep it fluid by the combustion of impurities in molten iron resulting from an air blast. The first converter he used was a cylindrical chamber lined with fireclay, having a row of tuyères near the bottom, and an opening at the top for the discharge of burning gases. It held 10 cwt. of metal in the molten state, and an air blast at a pressure of 15 lb./sq. in. was admitted through the tuyères and passed through the charge for about ten minutes. A violent emission of sparks, flame and melted slag occurred, lasting for some minutes. When this had subsided, the charge was tapped, and the metal proved to be wholly decarburised malleable iron. After many experiments, the converter first used was replaced by one mounted on a trunnion.

Bessemer's paper to the British Association was entitled 'The Manufacture of Malleable Iron and Steel without Fuel,' and within a month after giving it, he received £27,000 from iron manufacturers for a licence to use the invention. Unfortunately, the trials these men made were too hastily carried out: they were given insufficient attention, and the metallurgical knowledge of the licensees was inadequate. Consequently they failed, and much abuse was heaped upon Bessemer, whose process suffered considerable discredit.

By no means disheartened, he carried out fresh experiments, and in 1858, demonstrated clearly that he had passed the experimental stage of manufacture. His further attempts to use his process commercially now met with fierce opposition from the steel manufacturers. None of the Sheffield makers would adopt his process, even though he offered them a licence at £2 a ton. Each steelmaker insisted upon absolute monopoly, which Bessemer tenaciously refused to grant.

The only way in which he could overcome the prejudice and incredulity he encountered was to establish his own works in Sheffield, and in June of the same year, the first Bessemer steel works was selling tool steel at 44s./cwt., at which price it was quoted for the first time on the metal market. It was, however, not made by the true Bessemer process, but was molten iron decarburised



The observatory at Denmark Hill.

by the air blast and cooled in water, then re-melted in the crucible together with enough manganese to produce the desired carbon content.

Twenty years later (1879) Thomas perfected a basic lining which made possible the elimination of phosphorus in the converter, so extending the scope of the Bessemer process. From 1865 onwards, Bessemer steel had to meet the competition of the Siemens process, but within five years of 1859, which year marked the completion of the development stage of the original Bessemer process, it had been adopted by all the steel-making countries of the world. Naturally, this revolutionary invention was not adopted without much controversy, the most famous of these controversies being that in which Robert Mushet featured.

Soon after 1859, Bessemer made guns in Sheffield, hundreds of them, for foreign governments, and but for the prejudice of the War Office, Bessemer steel would have been used for British military weapons twenty years sooner than it was. Fortunately, no war involved Britain during that period, or she might have had to pay dearly for military ignorance. The first Bessemer steel rails were rolled at Crewe from ingots of Bessemer steel cast in Sheffield, and these were put down at Crewe in 1861.

Suspended Saloon for Ships

Bessemer had by now become a rich man, but his patents had not much longer to run. He turned his attention to the prevention of sea-sickness by means of a ship with a swinging saloon. A great sufferer from *mal-de-mer* himself, he invented a saloon which would move on an axis parallel with the line of the keel, and which, whatever the rolling of the boat, would remain level. A company was floated and a trial ship embodying the saloon built. Thousands of pounds were expended on fitting her out, and the first trip was minutely and carefully organised. On a beautiful calm day, in broad daylight, at a carefully chosen time of the tide, she sailed across the Channel.

Despite the skill of the best navigator available, the ship dashed into the pier at Calais after the second of three attempts to enter the harbour, doing damage for which the authorities claimed the exorbitant sum of £2,800, an undertaking for which had to be given before the vessel was allowed to depart. The mishap was not owing to failure of the saloon or its controlling machinery, but to the refusal of the vessel to answer her helm.

A second catastrophe at Calais discredited the Company, and Bessemer, who had lost thousands of pounds, abandoned the invention. The later history of the saloon is interesting. It was removed from the ship, because its rolling threatened to capsize the vessel, and taken to a private house at Swanley. In the 1890's this house became the Swanley Horticultural College, and the saloon, built on to it and supplied with a slate roof, was turned into a lecture hall, which was also used for entertainments and dances. The old leather seats still remained in place around the walls, and there were some beautiful carved panels, with the monogram B.S.S. Co., and twisted mahogany pillars supporting the roof. When the College was closed, the saloon-hall was offered for sale, but its present whereabouts are unknown to the author.

The guns made by Bessemer in Sheffield were of simple solid forged steel, 12, 18 and 24-pounders, and were sold ready for finish boring at £45/ton, being made from Bessemer mild steel. Bessemer hammered or forged his small Bessemer ingots into round bars and afterwards bored them, but the first gun of this type which he made was an 18-pounder from the first large-sized Bessemer steel ingot made in Sheffield at his own works. His large steam hammer had not been delivered at that time, and he could not therefore handle the ingot himself, but as soon as it was cool enough not to set the truck on fire, he sent it to Galloway's of Manchester, where it was forged into an old-fashioned gun, now in the possession of the Iron and Steel Institute. He also supplied Captain Blakeley with steel tubes for forged steel guns complete in one piece with the trunnions formed thereon out of the solid ingot.

It is known that in all these instances the guns were bored out in the lathe, and Bessemer himself says he supplied over 70 to foreign governments. Sir William Armstrong was so strongly entrenched at the War Office with his welded guns that Bessemer could not obtain a trial. He supplied rifle barrel steel in 1862 to Mr. Thompson of Bilston, and many thousands of rifle barrels (hammered) were made from this at Rotherham.

During the later years of his life Bessemer erected a magnificent observatory on Denmark Hill. He built a telescope of special design, and devised a mechanism for grinding and polishing the lenses. He also experimented unsuccessfully with the application of solar energy for the production of high temperatures. For a grandson he designed a plant for cutting and polishing diamonds.

Honours

Many were the honours bestowed upon Bessemer. In 1872, he was awarded the Albert Gold Medal by the Society of Arts for his services in developing the manufacture of steel. He was one of the founders of the Iron and Steel Institute in 1868, and on retiring from the office of President which he held from 1871 to 1873, he presented to the Institute an endowment for the annual presentation of a gold medal named after him. Bessemer who joined the Institution of Civil Engineers in 1877, received the Telford Gold Medal of that body in 1858, and the Howard Quinquennial Prize in 1878. In 1879, he was elected a Fellow of the Royal Society, and in the same year he received a belated knighthood for his services to the Inland Revenue Office many years before. On the 13th May, 1880, Bessemer was presented with the Freedom of the City of London, at a specially convened meeting at Guildhall. He also received the Freedom

of the City of Hamburg, and six towns and one city in the United States of America have been named after him.

Bessemer married, in 1833, Ann Allen of Amersham, by whom he had two sons and a daughter. His wife pre-deceased him by a year, Bessemer himself dying at Denmark Hill on 15th March, 1898; he is buried in Norwood Cemetery.

Removal and Recovery of Sulphur from Fuels

Institute of Fuel Conference

THE recent Conference on Removal and Recovery of Sulphur from Fuels, organised by The Institute of Fuel in London, was attended by fuel technologists, engineers and scientists from this country and overseas, including representatives from Belgium, Denmark, France, Germany, Holland, Italy and Sweden. The proceedings were opened by Sir John Maud, K.C.B., C.B.E. (Permanent Secretary, Ministry of Fuel and Power), who was introduced by the President, Dr. W. Idris Jones, C.B.E.

Thirteen papers were presented by scientific authorities of wide experience in the removal and recovery of sulphur in specific industrial processes. The discussions, which ranged over a wide field, were summarised at the close of the Conference by the official Rapporteur, Dr. J. G. King, O.B.E.

The following general conclusions, taken from Dr. King's summary, were endorsed by the Conference.

(1) The main source of indigenous sulphur is that contained in our coal. This amounts to over 3 million tons per annum and we now recover only 5–6% of it. Sulphur in petroleum represents another 600,000 tons and we are aiming to recover only 5% of that.

(2) The recovery of a higher proportion is essential for reasons of national economy, since we now import 75% of our sulphur requirements. Action is made more pressing (*a*) by the deleterious effects of sulphur in industrial processes, particularly metallurgy and glass; and (*b*) by injury to buildings, plants and human health by oxides of sulphur emitted to the atmosphere.

(3) Sulphur in the coal seam is rising slowly and in fuel oil has risen markedly, and every effort must be made to find means of reducing sulphur content after mining the coal or before marketing the oil in such a manner that recovery in usable form is possible. The industrial value of a lower sulphur content of fuel to industry is not clearly defined, and some definition should be attempted in order to assess the possible value of removal processes, since these are likely to be expensive. Coal of high caking power and low sulphur content may have to be reserved, or medium-sulphur-content coal cleaned, to provide low-sulphur coal to the iron and steel industries. Unless fuel oils can be reduced in sulphur content, this will impose some limitation of usage in processes where sulphur is a difficult factor.

(4) The gas industry now recovers 40% of the sulphur of its coal by effective means. A number of large-scale flow methods are now available, but there are doubts as to their suitability for British conditions and as to their operating costs. They will remove 70–80% of the hydrogen sulphide from gas, but the real consideration is whether any process can be worked in a given environment so as to produce by-product sulphuric acid or sulphur on an economic basis. The cleaning of coke-oven gas not now cleaned could add 60% to the gas industry's contribution to indigenous sulphur.

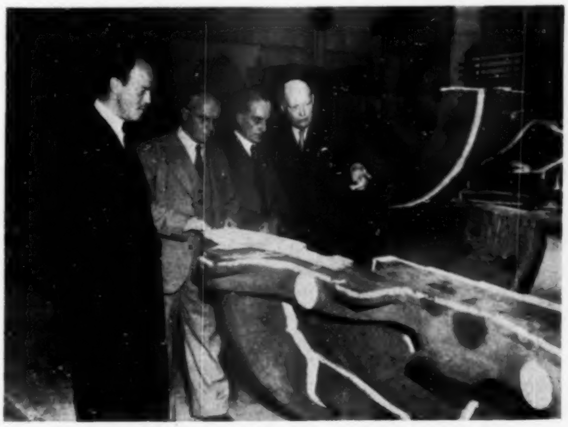
(5) Combustion gases from very large power stations are a potentially large source of sulphur of which effective recovery is more than desirable, as well as its removal from the atmosphere.

(6) It is regrettable that no new indigenous source of sulphur has been disclosed by the Conference, but the papers have focused interest so strongly on existing methods of recovery that this surely must give added impetus to further industrial action.

The Organising Committee, under its Chairman, E. C. Evans, is to examine the implications of the papers and discussions from the Conference and present a report to the Council of the Institute.

B.E.A. Engineers Visit D.B. Foundry

FOLLOWING their quarterly meeting, held in Leeds recently, Chief Generation Engineers (Construction) of the British Electricity Authority visited the Penistone works of The David Brown Foundries Company, one of the leading British suppliers of turbine castings for power stations at home and overseas. Several examples of this specialised work were seen by the B.E.A. engineers during their tour of the works, where they were received by Mr. G. L. Hancock, director and general manager of the David Brown foundry group.



Mr. Hancock welcomed the visit as an opportunity for an exchange of views between engineers who knew the requirements of the turbine operator and technicians whose task it was to solve the problems encountered in producing the steel castings of the right quality. The David Brown Foundries Company, he said, was anxious to co-operate in the development of generating plant, to which the company was continually devoting a considerable share of its research and technical resources. They were already supplying high pressure turbine castings weighing up to 8 tons to leading turbine manufacturers and in recent years the Penistone company had completed sets for sixteen power stations in the United Kingdom. In addition five sets had been supplied to South Africa and two more to power stations in Canada.

Beryllium as an Alloying Addition

By L. David

Quite small additions of beryllium can effect appreciable changes in the properties of various alloys, so that, although it is a relatively expensive metal, its use for such purposes may represent an economy. In the following article, attention is directed to the use of beryllium in alloys of magnesium, aluminium, nickel and copper, with particular reference to the last named.

UNTIL recently regarded as scarce, beryllium is now relatively plentiful. Improved production facilities and the discovery of many new sources of beryl, the ore from which beryllium is extracted, have combined to make possible the increasing use of beryllium in alloys and other industrial products. The diversity of application of beryllium in modern industry arises from its extreme versatility. As a pure metal, it has been valuable in X-ray work since 1926, and it is already established as a material of prime importance in nuclear energy applications. Its oxides have contributed significantly to recent advances in ceramics and industrial chemistry.

Beryllium in Light Alloys

Small additions of beryllium to aluminium and magnesium alloys often have a beneficial effect on the manufacturing procedure. Improvement in properties of the resulting alloys may also result from the incorporation of quite small quantities of beryllium. In the case of magnesium-rich alloys, 0·001% has been found to suppress the formation of magnesium nitride, which is difficult and expensive to remove from the surface of magnesium alloy slabs. A similar amount permits the use of green sand moulds, thus eliminating the tedious and costly procedure of complete removal from the mould of all traces of moisture. It has been stated that beryllium additions coarsen the grain, but by proper control the grain size can be kept within commercial specifications.

Some time ago it was found that small additions of beryllium to aluminium alloys containing magnesium practically eliminated the tendency for magnesium compounds to separate and come to the surface of the melt, with consequent rapid oxidation. It has been determined that beryllium contents in excess of 0·0005% are effective in stopping the segregation of magnesium in the molten alloy. Beryllium additions of 0·01–0·05% contribute to the thermal stability of aluminium alloys and make them easier to cast, and where intricate detail is required, 0·2% or less of beryllium will improve the fluidity and castability. It is also reported that beryllium additions refine the grain structure of aluminium alloys.

Other possibilities for the use of beryllium in aluminium alloys include the production of the so-called "stainless" aluminium, where the beryllium provides a tenacious oxide film on the surface, thereby, it is claimed, protecting the latter from discoloration and blistering. Beryllium additions also have beneficial effects in the hot dip coating of steel with aluminium.

Beryllium-Copper Wrought Alloys

The best known and most widely used of all beryllium alloys is beryllium-copper which is also produced in the greatest variety of composition and forms. This is the result of early interest in the salient features of this remarkable material—its ability to be hardened by a low temperature treatment from a relatively soft and workable state to levels of strength and hardness far beyond those of the more usual copper-base alloys. Many of the properties associated with copper are retained in large measure, even in the heat-treated state, and besides exhibiting good thermal and electrical conductivity, beryllium-copper has excellent resistance to corrosion; in addition it is non-sparking and non-magnetic.

In electrical equipment, beryllium-copper provides excellent mechanical properties for current-carrying springs and contacts, and its high fatigue strength has been put to good use by product designers in countless applications. Electronic devices frequently include components presenting problems of fabrication and service which could not be solved without the help of beryllium-copper. Instruments and controls rely heavily on the precise action of beryllium-copper diaphragms, bellows and springs, and use of the alloy in the automotive, aviation and machinery industries, although already large, is constantly growing. Established applications include automobile heater controls, ignition parts, terminals, aircraft gauge elements, plug-type connectors, fuel injectors, machine tool components, oil seals, and retaining rings.

Many obstacles had to be overcome in perfecting rolling, drawing, annealing and pickling practices, but the establishment of proper techniques has resulted in the availability of uniform beryllium-copper in strip, rod, bar and wire form. There is, in addition, a wide choice of tempers to meet specific requirements. Standardisation of production and specifications has firmly established beryllium-copper as a valuable engineering alloy.

In the solution-treated conditions, beryllium-copper is soft and can readily be worked and formed. It is fabricated by standard production methods: strip, for example, is easily blanked, formed, deep drawn or spun, whilst rod and bar respond to hot or cold forming methods, including forging, swaging and machining. Then, after fabrication, a simple low-temperature heat treatment imparts to beryllium-copper parts a remarkable degree of hardness and tensile strength, whilst substantially increasing the electrical and thermal conductivities.

The basic raw material for the introduction of beryllium is a beryllium-copper master alloy containing 3·5–4·25% beryllium, which the user adds to his melt in appropriate proportions. The standard high performance beryllium-copper alloy contains 1·8–2·05% beryllium and 0·18–0·30% cobalt. When fully heat treated it combines good electrical conductivity with the highest

strength and hardness of any copper alloy. Because of its excellent resistance to fatigue, corrosion and wear, this non-magnetic alloy is ideally suited for springs, diaphragms, bellows, miscellaneous electrical and electronic equipment, aircraft engine parts, bearings, cams, flash welder dies, and many other components. There is a lower-cost version of this standard alloy with 1·6–1·8% beryllium and 0·18–0·30% cobalt which offers good formability in the unhardened condition with good final properties.

The usual high conductivity alloy has moderate strength and contains 0·4–0·7% beryllium and 2·35–2·70% cobalt. This material is frequently specified for current-carrying springs, switch parts and similar components, where good electrical and thermal conductivity are more important than maximum strength and hardness. Another high conductivity alloy, with 0·25–0·5% beryllium, 1·4–1·7% cobalt and 0·9–1·1% silver, has been developed for resistance welding electrodes. Because of its good conductivity and hardness, combined with low surface contact resistance, it is used for spot, seam, flash and projection welding dies and electrodes. Typical properties of the wrought beryllium-copper alloys are shown in Table I.

A new beryllium-copper alloy for Bourdon tube applications, for use in aircraft, pressure and other gauges, is under development. Because of its high strength and hardness, coupled with good resistance to fatigue and in-elastic behaviour, this material will probably also find many other applications.

Beryllium-Copper Casting Alloys

A range of compositions of beryllium-copper and beryllium-nickel have been developed to meet the requirements of the many foundry applications. These materials are usually supplied in convenient sizes, ready for remelting and pouring, with the addition of hardeners or deoxidisers. In this way the foundry is relieved of the problem of alloying and a wide choice of final properties is obtainable by variations in the heat treatment of the castings. These alloys are relatively easy to handle by various existing techniques, and sand, investment, pressure, plaster-mould and permanent-mould castings have been made by established users. The group of casting alloys is characterised by excellent fluidity, which means that considerable detail can be obtained in the part as cast.

The most widely used beryllium-copper casting alloy contains 1·9–2·15% beryllium, 0·35–0·65% cobalt, and 0·20–0·35% silicon, with the following upper limits on impurities: iron, 0·25%; aluminium, 0·15%; tin,

TABLE I.—TYPICAL PROPERTIES OF WROUGHT BERYLLIUM-COPPER ALLOYS

Alloy	Form	Condition	Final Heat Treatment	Tensile Strength tons/sq. in	Yield Strength (0·2% offset) tons/sq. in.	Proportional Limit (0·002% offset) tons/sq.in.	Elongation % in 2 in.	Rockwell Hardness		Rockwell Superficial Hardness		Electrical Conductivity % I.A.C.S.
								B Scale	C Scale	30 T Scale	30 N Scale	
Be 1·8–2·05% Co 0·18–0·30%	Strip	A		27–35	12–16	6–9	35–60	45–78		46–67		17–19
		¼H		33–40	27–36	18–27	10–30	68–90		62–75		16–18
		½H		38–45	33–40	24–31	5–20	88–96		74–79		15–17
		H		44–54	42–50	31–38	2–7	96–102		79–83		15–17
		AT	3 hr. at 315° C.	73–85	62–76	44–56	4–10		36–41		56–61	22–25
		¼HT	2 hr. at 315° C.	78–89	67–81	49–61	3–6		38–42		58–63	22–25
		½HT	2 hr. at 315° C.	82–94	71–85	53–65	2–5		39–44		59–65	22–25
		HT	2 hr. at 315° C.	85–96	73–87	55–69	1–3		40–45		60–66	22–25
	Rod	A		27–38	9–14	6–10	35–60	45–85				17–19
		½H		38–58	33–47	15–29	10–20	88–103				15–17
		AT	3 hr. at 315° C.	73–85	64–78	44–56	4–10		36–41			22–25
		½HT	2 hr. at 315° C.	82–96	76–89	53–67	2–5		39–42			22–25
	Wire	A		26–35	9–14	6–10	35–55					17–19
		½H		49–61	40–49	26–36	2–8					15–17
		AT	3 hr. at 315° C.	73–85	64–78	49–61	3–8					22–25
		½HT	2 hr. at 315° C.	85–103	82–98	60–74	1–5					22–25
		PT		64–92	58–87	42–63	1–3					21–23
Be 1·6–1·8% Co 0·18–0·30%	Strip	A		27–35	12–16	6–9	35–60	45–78		46–67		17–19
		¼H		33–40	27–36	18–27	10–30	68–90		62–75		16–18
		½H		38–45	33–40	24–31	5–20	88–96		74–79		15–17
		H		44–54	42–50	31–38	2–7	96–102		79–83		15–17
		AT	3 hr. at 315° C.	67–81	58–72	38–52	4–10		33–38		53–58	22–25
		¼HT	2 hr. at 315° C.	71–83	60–74	42–54	3–6		35–39		55–59	22–25
		½HT	2 hr. at 315° C.	76–87	64–78	47–58	2–5		37–40		56–60	22–25
		HT	2 hr. at 315° C.	80–89	69–83	49–63	1–3		39–41		59–61	22–25
		AM		44–52	38–45	24–34	18–22		18–23		37–42	28–33
		¼HM		49–56	44–49	33–40	15–19		21–26		42–47	28–33
		½HM		54–61	49–56	38–45	12–16		25–30		46–51	28–33
		HM		60–67	56–63	42–49	9–13		30–35		50–55	28–33
Be 0·4–0·7% Co 2·35–2·7%	Strip	A		17–25	9–14	4–9	20–35	20–45		29–45		25–30
		H		31–38	27–36	18–29	5–8	70–80		69–75		22–27
		AT	3 hr. at 480° C.	44–54	35–45	24–34	8–15	92–100		77–82		48–52
		HT	2 hr. at 480° C.	49–58	47–54	33–43	5–12	95–102		79–83		48–52
	Rod	A		17–25	9–14	4–9	20–35	20–45				25–30
		½H		27–36	24–34	15–29	10–15	60–75				22–27
		AT	3 hr. at 480° C.	44–54	35–45	24–34	10–25	92–100				48–60
		½HT	2 hr. at 480° C.	49–58	44–54	31–40	8–20	95–102				48–60
Be 0·25–0·5% Co 1·4–1·7% Ag 0·9–1·1%	Rod	A		17–25	9–14	4–9	20–35	20–45				25–30
		½H		27–36	24–34	15–29	10–15	60–75				22–27
		AT	3 hr. at 480° C.	44–54	35–45	24–34	10–25	92–100				50–52
		½HT	2 hr. at 480° C.	49–58	44–54	31–40	8–20	95–102				50–52

TABLE II.—MINIMUM PHYSICAL PROPERTIES OF SOME CAST ALLOYS

Alloy	Heat Treatment		Tensile Strength tons/sq.in.	Yield Strength (0·2% offset) tons/sq.in.	Elongation % on 2 in.	Rockwell Hardness		Izod Impact Strength ft.-lb.	Electrical Conductivity % I.A.C.S.
	Solution	Precipitation				B Scale	C Scale		
Beryllium-Nickel ..	—	5 hr. at 565° C.	56	31	2	—	30	10	3
Beryllium-Nickel ..	1070° C.	5 hr. at 510° C.	87	80	0	—	52	10	3
Beryllium-Copper ..	—	2 hr. at 345° C.	38	20	15	90	—	50	18
Beryllium-Copper ..	800° C.	2 hr. at 345° C.	69	51	0	—	38	8	18
"S" Monel	870° C.	595° C.	49	36	1	—	32	1	3
Aluminium Bronze ..	885° C.	540° C.	49	29	5	—	24	—	13

0·10%; lead, 0·02%; zinc, 0·10%; nickel, 0·20%; chromium, 0·01%. Tensile strengths of 77 tons/sq.in. min., and hardnesses of Rockwell C38 min. are attained by solution treatment followed by precipitation hardening. A large and growing number of precision investment castings are being made from this alloy, because of its excellent fluidity and low pouring temperature. Typical applications employing sand and other casting techniques include bushings, cams, scraper blades and electronic parts. Beryllium-copper non-sparking tools afford protection against fire and explosion in hazardous areas and are claimed to be superior to all other copper alloy safety tools.

An alloy similar to the above, but with a beryllium content of 2·5–2·75%, is used for pressure cast moulds for plastics and certain other applications which require a material combining castability, strength, hardness and wear resistance in high degree with good thermal conductivity.

Other alloys designed for current-carrying members in heavy electrical equipment are high conductivity beryllium-coppers combining good resistance to wear and reliable service at moderately elevated temperature. The beryllium content is normally 0·5% and castings are heat treatable to a hardness of Rockwell B 92 min. with a conductivity of 45–50% I.A.C.S. This alloy offers the resistance welding industry an electrode material which has strength, conductivity, and low surface contact resistance.

Beryllium-Nickel Casting Alloys

Beryllium-nickel, an alloy containing some 2·75% nickel, has proved its worth in casting applications because it is easy to produce cast parts which can be heat treated to give good physical properties. Corrosion resistance is of the type normally expected of a high nickel material since the base metal is present in excess of 96%. The alloy for general use has a maximum carbon content of 0·5%, but there is another alloy with a higher carbon content (0·75–1·10%) which is easier to machine: the latter alloy has, however, somewhat lower final properties.

Coke-fired furnaces and graphite crucibles should be avoided for melting beryllium-nickel, due to the dangers of carbon and sulphur pick-up. Induction or arc melting is preferred, and the crucibles should be neutral or basic. Heat treating the "as-cast" material for 5 hours at 565° C. gives a minimum tensile strength of 56 tons/sq.in. but, as will be seen from Table II, a figure of 87 tons/sq.in. can be attained by water quenching from 1,070° C. followed by 5 hours at 510° C.

Beryllium-nickel is most advantageously used where design requirements call for extremely high strength and hardness, combined with good corrosion resistance. It also has good wear resistance in rotating parts, and its fluidity in the molten state has led to its use in the production of small detailed investment castings. Typical applications of beryllium-nickel include pump impellers, mining drill bits and miscellaneous aircraft components.

Life in 2,000 A.D.

THE result of the Royal Society of Arts Bicentenary Competition for forecasts of practical aspects of life on this earth in the year 2,000 A.D. is now announced. The judges appointed by the Council of the Society were unable to make any recommendation for the first prize of £250 or the second prize of £100, but the Council has made the following awards :—

A prize of £50 to Wing Commander T. R. Cave-Browne-Cave, C.B.E., M.I.Mech.E., F.R.Ae.S., of Southampton. For a scheme for rooftop roadways.

A prize of £20 to C. E. H. Watson, B.Sc. (N.Z.), M.I.C.E., A.M.I.Mech.E., A.M.I.Struct.E., of Walton-on-Thames. For a system of underground roadways for London.

A prize of £10 to F. R. East, A.C.I.S., of Horbury, near Wakefield. For a paper on synthetic food.

A prize of £10 to The Rev. C. W. Gibbons, B.Sc., of Cambridge. For a paper on education.

A prize of £10 to M. B. McEvedy, M.A., B.M., B.Ch., D.Obst., of Manchester. For a paper on microbiological products.

The Council have decided to invite the first two prizewinners to read their essays as papers at a meeting of the Society at 2.30 p.m. on Wednesday, November 24th, 1954. The papers, with any following discussion, will be published in the Society's Journal almost immediately afterwards. A summary of the other prize-winning essays will also be published in the Journal.

Jarrow Tube Works

AT the end of July, Tube Investments Ltd. announced that Jarrow Tube Works Ltd., would cease production on 31st October, 1954, owing to the entry into production of new TI plant in the Midlands. Following recent increases in home and overseas demand for certain classes of tubes, it has been found possible to continue production at Jarrow.

B.T.H. Nottingham

To give greater service to customers in Nottingham and District, Mr. J. N. Griffiths, who has previously handled the Electrical Plant and Apparatus business from B.T.H. Sheffield Office, is now located in the B.T.H. Nottingham premises, 71–73, Lower Parliament Street, (Tel.: Nottingham 43588).

Drip Feed Gas Carburising

Wild-Barfield Introduce Carbodrip Process

ALTHOUGH it has by no means entirely replaced the pack carburising process, the gas carburising of ferrous alloys has now become well established in the engineering industry as a method of case hardening a large variety of components. Apart from economic considerations, the most important advantage of gas carburising is that of precise metallurgical control of the quality of the case. By the application of the diffusion principle, a eutectoid composition can rapidly be produced: instead of carburising slowly at a low temperature in order to avoid the formation of a hyper-eutectoid material at the surface, cementation can be carried out much more rapidly at higher temperatures and the excess cementite removed by subsequent diffusion to produce a final case of eutectoid composition.

The atmospheres used for gas carburising aim at obtaining a reaction mixture containing carbon monoxide, methane and hydrogen, in suitable proportions, with deterious constituents like carbon dioxide, oxygen and water vapour removed entirely or reduced to a very low figure. Partially burnt town's gas may be used as a "carrier," with additions of propane or butane to strengthen it sufficiently for carburising purposes. As a result of their investigations into the problems of gas carburising, Wild-Barfield Electric Furnaces, Ltd., developed a method, known as the Prepared Town's Gas (P.T.G.), Process which obviates the need for the somewhat expensive addition of butane or propane. Town's gas is the basic raw material and this is treated in such a way as to remove its deleterious constituents, including carbon dioxide, water vapour, oxygen and organic sulphur compounds, without serious interference with the carburising constituents present in the raw gas. Typical analyses before and after treatment are shown in Table I. One of the advantages claimed for the process is that the absence of the higher hydrocarbon additions enables carburising to take place at a higher rate without risk of harmful sooting.

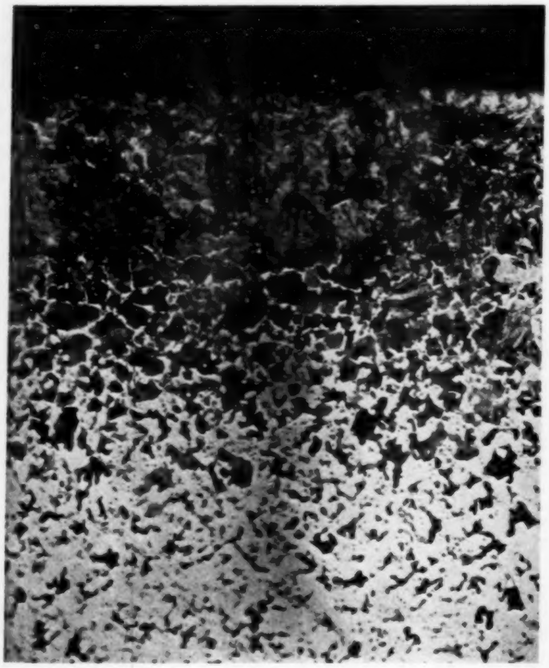


Fig. 1.—Photomicrograph of En. 32 steel gas carburised in a Carbodrip atmosphere at 925° C. Total time, 2¾ hours; total case depth, 0·039 in. × 50

TABLE I.—ANALYSIS OF TOWN'S GAS BEFORE AND AFTER PREPARATION.

Constituent	Raw Town's Gas—%	Prepared Town's Gas—%
Carbon Dioxide	3·3	0·0–0·2
Oxygen	0·6	0·0–0·1
Unsaturated Hydrocarbons	2·1	0·4–0·6
Carbon Monoxide	16·4	20·2
Methane	24·0	23·6
Hydrogen	49·5	51·2
Nitrogen	4·1	Bal.

Requirements of the Carburising Liquid

It was with this background in mind that the Company's Research Department approached the problem of drip-feed carburising, in which a suitable organic liquid, such as a mixture of alcohols and hydrocarbons, is dripped directly into the carburising furnace chamber with the intention of producing the reaction gas directly *in situ*. Not unnaturally, the aim of the research programme was the development of a liquid mixture which would pyrolyse to give a carburising gas of composition similar to P.T.G., without decomposition to carbon as part of the reaction cycle. If such a liquid could be found, it would be fair to assume that the atmosphere derived from it would carburise at the same rate as P.T.G., and that diffusion periods of the same order would be required to produce cases of eutectoid composition. Conditions of carburising would remain standard and the long history of experience, including time-penetration data for a wide range of steels, would be available for use with the new process.

In order to be completely satisfactory it was decided that the medium should also fulfil the following conditions :—

(*a*) The atmosphere derived should be virtually free from decarburising gases, such as carbon dioxide, oxygen and water vapour.
(*b*) Deleterious sulphur compounds should be absent.
(*c*) Undue sooting, with its consequent "stopping-off" effect should not occur.
(*d*) The drip rate should not be critical from the metallurgical viewpoint.
(*e*) The liquid mixture should be readily available and relatively inexpensive.

The search was successfully concluded a few months ago, and the liquid mixture, known as Carbodrip, has been shown to give consistently an atmosphere very

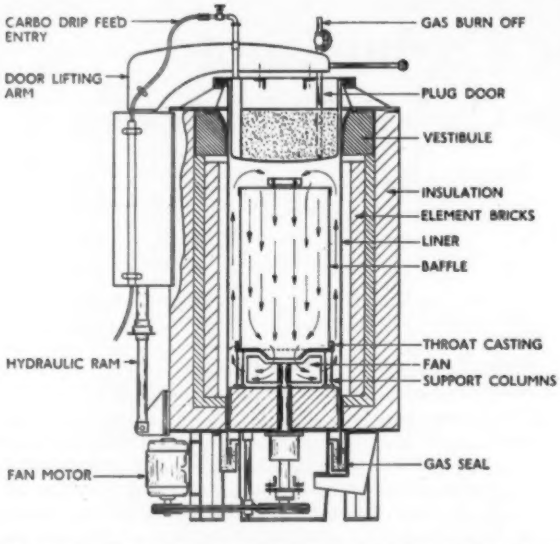


Fig. 2.—Sectional diagram of a fixed retort gas carburising furnace for use with Carbodrip feed.

similar to P.T.G., and to behave similarly in carburising tests, as can be seen from Tables II and III. Carbodrip is also suitable for use, in conjunction with ammonia, in carbonitriding.

TABLE II.—ANALYSIS OF CARBODRIP ATMOSPHERE COMPARED WITH P.T.G.

Constituent	P.T.G.—%	Carbodrip Atmosphere—%
Carbon Dioxide	0·0–0·2	0·0–0·3
Oxygen	0·0–0·1	0·0–0·2
Unsaturated Hydrocarbons	0·4–0·6	0·2–0·6
Carbon Monoxide	20·2	20·0–25·0
Methane	23·6	20·0–25·0
Hydrogen..	51·2	58·0–48·0
Nitrogen	Bal.	—

TABLE III.—PRACTICAL CARBURISING RESULTS WITH CARBODRIP COMPARED WITH THOSE WITH P.T.G.

Steel Carburised	Temperature °C.	Total Time(T) hr.	T/t ratio*	Atmosphere Used	Case Depth—In.	
					Total	Eutectoid
En. 32	925	2·75	1·4	Carbodrip P.T.G.	0·039 0·040	0·023 0·022
En. 32	950	1·60	1·5	Carbodrip P.T.G.	0·041 0·040	0·023 0·022
En. 34	925	3·20	1·55	Carbodrip P.T.G.	0·042 0·040	0·026 0·025
En. 34	950	3·10	1·75	Carbodrip P.T.G.	0·050 0·050	0·033 0·032
En. 36	925	5·25	1·60	Carbodrip P.T.G.	0·050 0·050	0·037 0·036
En. 36	950	4·75	1·85	Carbodrip P.T.G.	0·060 0·060	0·045 0·044
En. 39	925	9·00	2·0	Carbodrip P.T.G.	0·065 0·062	0·045 0·045
En. 39	950	9·20	2·3	Carbodrip P.T.G.	0·072 0·070	0·056 0·055

* t is the time during which active carburising takes place. T-t is, therefore, the diffusion period.

Equipment Used

The furnaces used for drip-feed carburising are of standard vertical design, and incorporate a liner which has a positive clamped seal at the top and a chrome-ore seal at the bottom. To ensure efficient gas circulation, a powerful centrifugal fan is provided at the base of the furnace, together with an inner drum which is located centrally on the throat casting. With this method of carburising, furnaces smaller than those used for normal gas carburising are considered to be economical, due to the very much lower capital cost of the atmosphere handling equipment. Such furnaces are being designed to meet the demand of the smaller heat-treatment establishments for gas carburising equipment.

The Carbodrip liquid mixture is contained in a vessel of approximately 10 gallons capacity, fitted with a well protected sight glass, a pressure gauge, a filler cap, and a safety valve. The motive force to drive the liquid is compressed air at 5–10 lb./sq. in. pressure, which is fed to the vessel by means of an air line provided with a water trap and a pressure-reducing valve. Thus the liquid is forced to flow up a pipe via a liquid filter, a fine-control needle valve, a liquid flowmeter and a

Fig. 3—(left). General view of GCF. 1630F gas carburising installation working on the Carbodrip system.

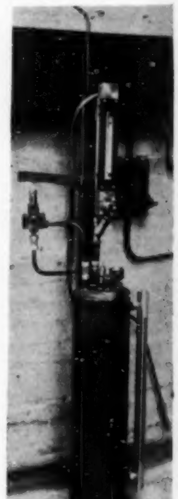


Fig. 4—(right). Close-up of Carbodrip handling equipment seen in Fig. 3.

flexible pipe to a jet in the furnace door. The indicating flowmeter is provided to enable accurate control of flow to be attained, and thus minimise waste of the Carbodrip liquid. Where there is no works supply of compressed air available, a small portable compressor and capacity vessel will suffice.

Having drip-feed carburised a charge of work, it can be cooled slowly in a refractory pit fed with a protective atmosphere. Alternatively, if metallurgical and production requirements warrant it, direct quenching may be carried out. In the latter case, special consideration must be given to the design of carriers and baskets to ensure that the cooling rate of the charge is as rapid and uniform as is necessary to obtain the desired results.

In comparison with orthodox gas carburising, the Carbodrip process offers certain advantages, particularly on the economic side. A lower capital outlay is required for a given gas carburising programme, and power costs are lower owing to the absence of a catalyst furnace. Moreover, Carbodrip is free from sulphur compounds whose presence in town's gas may call for further expenditure for their removal. Maintenance costs are extremely low, and a saving in floor space results from the fact that the Carbodrip handling equipment occupies much less space than a gas plant.

A New Nimonic Development

Extruded Blade Sections with Cooling Passages

THE continual effort to improve the output and efficiency of the gas turbine has resulted in a corresponding desire on the part of designers to use ever higher gas temperatures. To a remarkable extent these increasingly severe operating temperatures have been met by the introduction of improved materials which have properties that, a few years ago, were regarded as unobtainable in any alloy.

From the introduction of the first of the Nimonic series of high-temperature alloys, one or other has been used for the moving blades of every British aircraft gas-turbine, and in addition the Nimonic alloys are now generally used for such components as flame tubes, stator blades, exhaust units and, in fact, for all vital components exposed to the gases at high temperatures.

By development of the alloys the useful operating temperature range has been steadily raised, but while these improvements are considerable, the gas-turbine designer must also employ every artifice to utilise these properties to the utmost advantage, and, therefore, the problem of blade-cooling has received a good deal of attention both in this country and abroad.

The problems involved are complex. Although other methods of cooling, such as sweat, thermosiphon, and other forms of liquid-cooling have been proposed, air cooling would appear to be the most convenient to apply. For this reason a considerable amount of production development work has been undertaken to produce blade sections with axial air passages. Casting and sintering have been tried for the production of sections with a large number of small cooling passages, but, in comparison with wrought materials of the same composition, castings suffer the disadvantage of being less uniform in properties, while the art of sintering has not yet been developed sufficiently to permit adequate mechanical properties to be obtained.

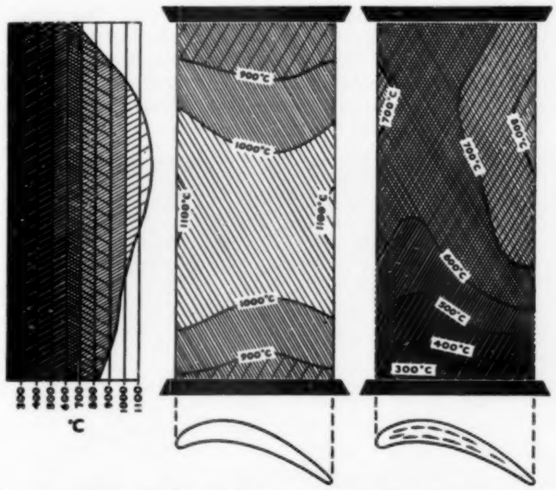


Fig. 2.—Effect of air-cooling on the operating temperatures of stator blades and on the heat distribution.


Fig. 1.—Some typical aerofoil sections successfully extruded showing different configurations of cooling passages.

The application of extrusion to the Nimonic alloys has opened up a wide field for further advancement. Service conditions necessitate the use of alloys which will be tough and stiff at high temperatures and yet must be amenable to hot-working. As new alloys have been added to the Nimonic series, there has been a corresponding reduction in the difference between the operating temperature, at which the alloy must be stiff, and the forging temperature, at which it must be reasonably malleable. A stage may therefore be reached when alloys for still more onerous service cannot be forged economically by normal techniques. The extrusion process extends the range of composition of alloys which can be commercially worked by breaking down the

coarse structure of the cast ingot, and thus improving forgeability so that ordinary hot and cold working operations can be used to give the desired final dimensions.

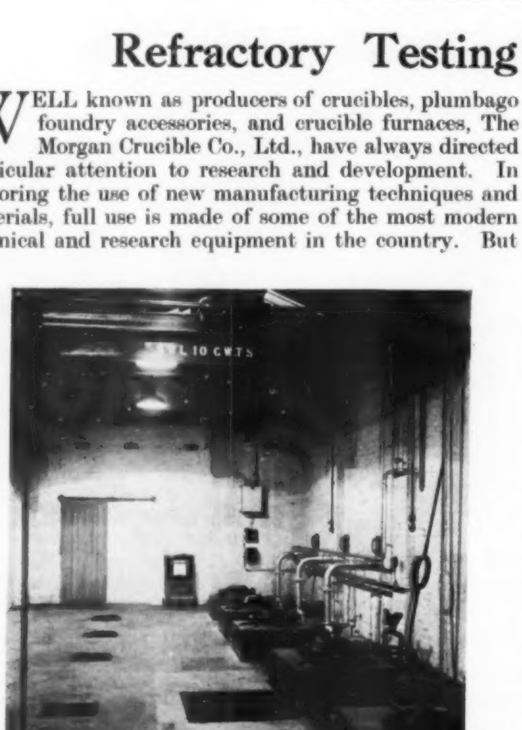
For some time the Zenith works of Henry Wiggin & Co., Ltd., have been producing Nimonic alloy aerofoil sections by hot extrusion and subsequent rolling. Work is now sufficiently advanced to enable a wide range of such forms (see Fig. 1) to be successfully extruded, including those containing various configurations of cooling passages.

It appears to be economically possible to produce cooled blade sections by this process, with passages limited in number, size and shape only by the operations involved in machining the original billet.

Fig. 2 gives some impression of the effect of air-cooling on the operating temperatures of stator blades and on heat distribution. Cooled blade sections are currently being produced in Nimonic 80A and Nimonic 90, offering all the characteristics of these alloys for uses where resistance to oxidation and thermal shock is required, but making these properties available for service with still higher gas temperatures, with consequent improvement in overall output and efficiency.

Refractory Testing Foundry Extension

WELL known as producers of crucibles, plumbago foundry accessories, and crucible furnaces, The Morgan Crucible Co., Ltd., have always directed particular attention to research and development. In exploring the use of new manufacturing techniques and materials, full use is made of some of the most modern technical and research equipment in the country. But



what will be of particular interest to readers is that, in addition to laboratory tests and other " back-room " activities, the Company maintains a test foundry at Battersea Works for more practical research. One of the main purposes of this foundry is to test and operate Morgan furnaces and Salamander crucibles under actual operating conditions—not only new furnace designs and test crucibles made in the course of development work, etc., but also batch samples of current crucible production. In addition to the testing and development work, a considerable amount of actual production casting work is carried out.

This testing foundry is continually being brought up to-date—by adopting the latest developments in melting practice, and by using the most modern types of crucible melting apparatus. A recent improvement at Battersea may not be without interest, and the illustration shows in some detail what has taken place. In one part of the foundry were some old-fashioned pit furnaces : these have been removed and replaced by the latest type L.O. oil-fired lift-out furnaces of 350 lb. bronze capacity.

The L.O. oil furnaces are supplied with air by a single fan, the fan and main trunking being situated outside the shop. The oil used is 200 seconds grade, and is supplied to the furnaces by a pumped ring main, being heated to atomisation temperature before being circulated. The heater and pump unit are installed in a separate pump house. The ring main pressure is 4 lb./sq. in., and to safeguard against air supply failure a push button switch is situated in the furnace shop which, when operated, shuts down the pump unit. The ring main is so arranged that by altering the valve sequence the main can be pumped dry, the oil returning to the main storage tank.

It may be of interest to note that other melting furnaces in the foundry include lift-out, tilting, rotary, and bale-out types. All this equipment, as well as providing a test shop for Morgan equipment, serves as a useful " show-room " where potential customers and other visitors can see products demonstrated under production conditions.

Aluminium Development Association and the C.I.D.A.

AT a recent meeting of the Council of the Aluminium Development Association it was decided that an invitation should be accepted to join the Centre International de Developpement de l'Aluminium. It may be recalled that the C.I.D.A. was set up some three years ago at the suggestion of the O.E.E.C., and it is constituted of five countries at present, namely, France, Italy, Switzerland, Germany and Austria. It has the fundamental aim of furthering the future development of aluminium by discussing problems of common interest among the participating organisations. The Secretariat of C.I.D.A. is located in Paris, at the offices of l'Aluminium Francais, under a Government Committee, the Chairmanship of which is held by Monsieur Dumas of the same organisation. The work has been carried forward through five committees established in 1951, namely, on architecture, transport, chemical applications, electrical engineering and publicity. It is understood that a technical committee on standards was set up at the end of 1953.

NEWS AND ANNOUNCEMENTS

Midlands Electronics Exhibition

THE Scientific Instrument Manufacturers' Association announce an exhibition of electronic aids to production, design, and research, under the title "Electronics at Work," to be held in Birmingham from the 23rd to 25th November, 1954, at the Chamber of Commerce Hall. Admission will be by ticket obtainable free on request from the Association at 20, Queen Anne Street, London, W.1, or from any of the following: Chamber of Commerce, 95, New Street, Birmingham, 2; Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2; City of Birmingham Information Department, 57, Corporation Street, Birmingham.

The exhibition theme, Electronics in Action, will be exemplified by a large number of working demonstrations showing the employment of electronics in a wide range of industrial applications, in public services, medicine, and education, and in varied spheres of research and development. In organising a practical display of demonstrations, the Association invites requests for tickets from all who may be primarily interested as users of electronics, in addition to inviting the attendance of electronic engineers.

Dowson and Mason Gas Plant Co. Ltd.

THE Board of United Gas Industries Ltd. announce that they have acquired the share capital of the Dowson and Mason Gas Plant Co. Ltd., engineers, gas plant and furnace specialists of Levenshulme, Manchester. The Board of the latter Company has been reconstituted with Mr. P. P. MacDiarmid, a director of United Gas Industries as Chairman. Mr. H. G. Wrigglesworth, the Group Financial Controller of United Gas Industries has been elected to the Board of Dowson and Mason and Mr. L. G. A. Leonard is to continue as Director and General Manager.

Driver-Harris Expansion

DEVELOPMENTS in the fields of application of nickel-containing alloys are proceeding at a rapid pace. The continuing spread and strength of the demand are such as to provide one of the most remarkable examples of scientific and industrial expansion in Britain in recent years.

To provide the greatly-increased production capacity necessary in meeting the demand for these alloys, British Driver-Harris Co. Ltd. have been carrying out a programme of extension of works and plant, and of laboratory and research facilities. The original programme, although of generous proportions, is having to be enlarged upon and information about further extensions is expected soon. In addition, a reorganisation at top-executive level has become necessary, because of the increased management responsibilities, details of which appeared in our Personal News column last month.

Scottish Coke Ovens Order

WOODALL-DUCKHAM CONSTRUCTION CO. LTD., of London have received the order for the new coke oven plant to be built at Ravenscraig, near Motherwell, by Colvilles Ltd. as part of their £20 million Scottish steel development scheme. The installation, valued at about £2½ million, will carbonise 1,600 tons of coal per day and will comprise 70 W-D Becker coke ovens, coal handling, storage and blending plant; coke handling and screening plant; by-products equipment; benzole recovery and rectification plant; and water recirculation and cooling equipment.

Reorganisation of the A.E.I. Group

THE Board of Associated Electrical Industries, Ltd., have decided to reorganise the A.E.I. Companies into four Groups: B.T.H. Group, Ediswan-Hotpoint Group, M-V.E. Group, and Overseas Group; the Chairman of of A.E.I. being Chairman of each of the Groups. The Group Managing Directors:—MR. E. H. BALL (B.T.H.); MR. A. N. E. MCHAFFIE (Ediswan-Hotpoint); DR. C. DANNATT (M-V.E.); and DR. I. R. COX (Overseas) are members of the A.E.I. Board, and form, with the Chairman, the Executive Committee of the Board.

The Group Managing Director of the Overseas Group will be the A.E.I. nominee director on the Boards of A.G.E., First Electric and Vecor, and will become Chairman of A.E.I. (India) and A.E.I. (Pakistan). The B.T.H. and M-V.E. Export Companies will operate as at present. To ensure the closest liaison, however, the Group Managing Director of the Overseas Group has become Chairman of the B.T.H. and M-V.E. Export Companies.

As part of the reorganisation, Mr. G. A. CHEETHAM, Managing Director of Ferguson Pailin, joins the Board of Metropolitan-Vickers. He continues as Managing Director of Ferguson Pailin.

Mr. W. E. Wright

To mark the completion of twenty-five years' service with the company, and as an expression of their esteem, his colleagues in the Metal Finishing Division and Laboratories have presented Mr. W. E. Wright, a Director of The Pyrene Co. Ltd., with a portrait of himself painted by S. J. Iredale.

Mr. Wright, who has been in charge of the Metal Finishing Division throughout the twenty-five years, was the first man to promote in this country the adoption on a commercial scale of phosphate processes for rust proofing and later for paint bonding. From the early Parkerising and Bonderising processes he has seen the development progress until there are now nearly thirty such processes in the Pyrene range. As a result of his work in this field, Mr. Wright was elected to the Fellowship of the Chemical Society in 1944.

EFCO Swiss Subsidiary

ELECTRIC FURNACE CO. LTD. announce the formation of a new subsidiary company in Switzerland. This is named EFCO Industrieofen, A.G., with the alternative French and English titles, EFCO Fours Industriels, S.A., and EFCO Industrial Furnaces, Ltd. The Administrative Board (Verwaltungsrat) consists of W. Schubarth (President), J. A. Monks and G. Schoeffter, and the registered office will be in Basel, Switzerland. The Company, which has a capital of 100,000 Swiss francs, will supply electric furnace equipment for all

types of industrial heat treatment, and also heat treatment salts and compounds.

New Telcon Branch Offices

The Telegraph Construction and Maintenance Co. Ltd., Telcon Works, Greenwich, announce the opening of a new Branch Office and Depot at 2, St. Nicholas Buildings, Newcastle-on-Tyne, 1, under the management of Mr. R. Fenwick. Stocks are carried of P.V.C. wiring cables and flexibles, and radio frequency and broadcast relay types of cables. The branch also handles enquiries for other Telcon products, including paper insulated mains cables, having copper or aluminium conductors and with either lead or aluminium sheathing, and products of Telcon's Plastics Division. The Company also announce the opening of a London Sales Office at Norfolk House, St. James' Square, S.W.1, under the management of Mr. A. W. Matkin.

The Institution of Metallurgists
Refresher Course

The Annual Refresher Course organised by the Institution of Metallurgists was held at the Palace Hotel, Buxton, from Friday, 22nd October, to Sunday, 24th October. The theme of the course was "The Inspection and Testing of Metals," and the following lectures were delivered on various aspects of the subject: "Inspection of Metals in Service," by G. A. Cottell; "Inspection in the Steel Industry," by J. F. Hinsley; "Inspection in the Non-Ferrous Metals Industry," by S. S. Smith; "Assessment of Methods of Non-Destructive Testing," by H. Harris; and "Batch Testing and Sampling," by H. J. Curnow. An exhibition of non-destructive testing equipment was open on the Saturday afternoon. The lectures presented at Buxton will be published in due course and will be available to non-members of the Institution.

Loudon Lecture

"Control Chart Technique and Production Efficiency" will be the subject of one of the Loudon Lectures organised by the University of Glasgow this winter. The lecture will be given in the Fore Hall of the University at 7.30 p.m. on 1st December, 1954, by Dr. B. P. Dudding, M.B.E., Vice-Chairman, Advisory Scientific Panel, Research Laboratories of The General Electric Co., Ltd., Wembley.

Change of Address

British Insulated Callender's Cables, Ltd., announce that their Bedford Depot has been closed down and a new depot opened at 81, Dumfries Street, Luton, Beds. The telephone number of the new Luton Depot is to be Luton 6866. Mr. W. H. Spillman is in charge.

Personal News

Metropolitan-Vickers Electrical Co., Ltd., announces that the Chairman, Sir George E. Bailey, C.B.E., and the Deputy Chairman, Sir Felix J. C. Pole have resigned from the Board of Directors. The Rt. Hon. The Viscount Chandos (formerly Mr. Oliver Lyttelton), P.C., D.S.O., M.C., has been elected a Director and Chairman of the Board.

The Stanton Ironworks Co., Ltd., has recently made the following appointments: General Works Manager, Mr. G. R. Buckley; General Manager in charge of Research, Mr. E. Morgan; Commercial Manager, Mr. L. Rawlins; and Export Manager, Mr. J. D. Hickman.

British Insulated Callender's Cables, Ltd., announce the following Board changes and appointments effective from 1st December, 1954: Mr. W. H. McFadzean, Chairman and Chief Executive, will become Chairman and Managing Director; Mr. D. W. Aldridge will become Deputy Chairman; Mr. H. J. Stone, Deputy Chief Executive will become General Manager; Mr. W. C. Handley, will become Deputy General Manager; Dr. L. G. Brazier, Director of Research, will become Director of Research and Education; Mr. R. M. Fairfield will be appointed to the Board as Director of Production and Engineering; and Mr. D. T. Hollingsworth will be appointed to the Board and will give up his present position as Chief Engineer to take up an important appointment in an associated company.

Mr. E. E. Blake has resigned his position as Chairman of Kodak, Ltd., but at the request of the Board he will continue as a Director of the Company and Adviser on Motion Picture matters. Mr. Blake is succeeded as Chairman by Mr. H. S. Carpenter, who will also continue as Managing Director. Mr. I. D. Wratten has been appointed a Deputy Managing Director.

Owing to pressure of business commitments, Sir Kenneth Hague, Deputy Chairman and Managing Director of Babcock & Wilcox, Ltd., has been compelled to resign his Chairmanship of the Associated Company, Edwin Danks & Co. (Oldbury), Ltd. General Sir Kenneth Crawford, K.C.B., M.C., has been appointed a Director of Edwin Danks and Chairman in succession to Sir Kenneth Hague.

Mr. D. G. W. Acworth, Manager of the Export Department of The General Electric Co., Ltd., has been appointed a Director of each of the overseas companies of the G.E.C. in Australia, New Zealand, South Africa, Central Africa, India, Pakistan, Burma, Malaya, Hong Kong and Canada.

On medical grounds, Lieut-Col. J. F. Todhunter has relinquished his appointments as Director and General Manager of Murex Welding Processes, Ltd. He is not severing completely his connections with Murex Welding Processes, and his services have been retained as a Consultant to the Company. Colonel Todhunter is succeeded as General Manager by Mr. J. M. Willey.

Two new Directors, Mr. H. H. Brieger and Mr. E. H. Muscroft, have been appointed to the Board of Cox & Danks, Ltd., the scrap and steel merchants of Park Royal, London. Mr. Brieger has also recently been elected to the Board of John Allan & Co. (Glenpark), Ltd., of Glasgow and Birmingham. Both companies are members of the Metal Industries Group.

The General Electric Co., Ltd., announces that in addition to his present responsibilities as Sales Manager of the London and Southern England Area, Mr. W. J. Bird has been appointed Deputy Sales Manager of the Company.

The Export Credits Guarantee Department announces that the President of the Board of Trade has appointed Mr. H. Douglass, General Secretary of the Iron and Steel Trades Confederation, to the Department's Advisory Council.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Radiograph Processing Unit

The Kodak Processing Unit Model 30 should appeal to all those whose work calls for the processing of small batches of radiographs on a scale which does not justify the installation of large and expensive equipment. It is ideally suitable for darkrooms associated with hospital operating theatres, for small hospitals and private radiological practices. This small, self-contained, thermostatically-controlled unit will also be welcomed in the graphic arts, industrial and other fields for the processing of both plates and sheet film.

Constructed of resin-bonded plywood, the processing unit is divided into a water jacket and a wash compartment. The water jacket contains three 3-gallon Kodak No. 173 hard rubber tanks, one for developer and two for fixer. Four films in hangers in sizes up to and including 14 in. × 17 in. can be contained in each tank. The developing tank, which is fitted with a lid, is separated from the two fixing tanks by a rinse compartment of the dip-rinse type which will take four films in hangers.

The water in the water jacket is heated by a 300-watt immersion heater suitable for 200/250 volt A.C., and is controlled by a Sunvic thermostat. The level of the water is controlled by an overflow built into the rinse tank. Ten film hangers of all sizes up to 14 in. × 17 in. can be accomodated in the wash compartment, supported on two stainless-steel racks. Water enters through a rose feed in the bottom of the compartment and overflows at the top through a stand pipe.

Simplicity is the keynote of this new processing unit, for it is simple to install, maintain, operate and clean. Nevertheless it contains many of the outstanding features of the larger and more expensive units.

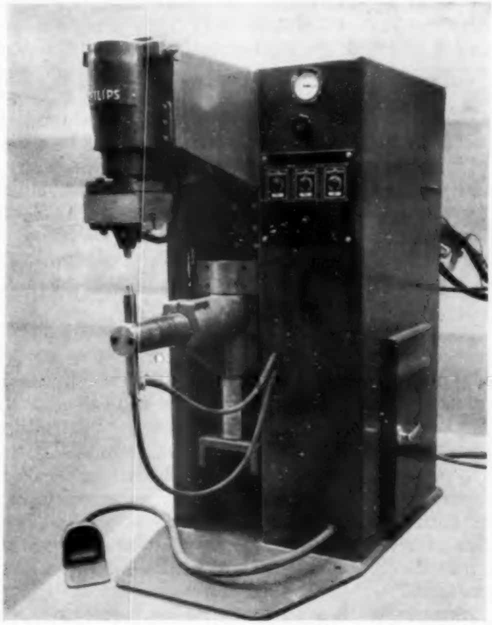
Kodak, Ltd., Harrow, Middlesex.

Heavy Duty Spot Welder

A new heavy duty spot welding machine—the P.E.1020—has been introduced by Philips Electrical Limited. It has been specifically designed for arduous duty on the heavier gauges of mild steel and has a welding capacity in that metal of up to $\frac{1}{4}$ in. plus $\frac{1}{4}$ in. added thickness; it is also suitable for spot welding light alloys up to 16 plus 16 s.w.g. added thickness. When used in conjunction with Philips Tempomat synchronous time control equipment, excellent results are obtained in welding stainless steels and Nimonic alloys.

The machine is fully automatic for both single and repeat operation, ensuring accurate repetition of any predetermined welding sequence. Welding speed on repeat is up to 100 spots per minute. Three Philips thyratron plug-in unit timers give precise control of weld time, forge time and off time, and switching of the primary current is by means of an ignitron contactor, fitted with Philips type P.L.5551 ignitrons. An electro-mechanical contactor can be fitted as an alternative to the ignitrons.

Welding pressure is applied by means of an air cylinder, which incorporates a built-in adjustable air switch, to ensure that weld initiation takes place only at the correct pressure. Welding pressure is indicated by a gauge marked in pounds, calibrated against the size of air cylinder employed. The lower arm of the machine is adjustable, both horizontally and vertically, and provision is made for either vertical or offset stakes. Electrodes are all to B.S.S. 807 standards.



This type of machine is available with a choice of three throat depths, namely 18 in., 24 in. and 30 in., and can also be fitted with a high lift head, to facilitate welding of components which have deep flanges to be overcome, whilst employing only a short welding stroke.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

New Automatic Arc Welding Electrode

A new continuous electrode for automatic arc welding has been developed by Murex Welding Processes, Ltd., Waltham Cross, Herts. This electrode, known as Coilex, is double-wire wound flux extruded and it is suitable for use with all types of D.C. automatic welding machines designed for continuous coated electrodes.

Coilex has been developed for the welding of mild and medium tensile steels, and it can be used for either butt or gravity fillet welds in all classes of steelwork normally considered suitable for welding. The flux is of the basic type and thus the electrode can also be used for the welding of difficult steels, or for making joints in mild steel under conditions of contraction restraint. Among the many special features of the Coilex electrode are a

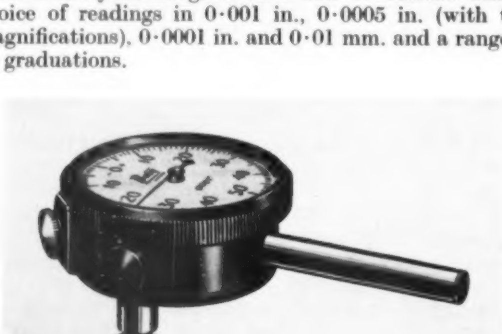
high rate of deposition and deep penetration, consistent burn-off, good weld appearance and easy striking. Good radiographic results can also be obtained. The electrode has a special robust construction. Instead of following a conventional helix, the outer wire winding of Coilex is applied with a series of definite " sets " to form a number of minor projections above the surface of the extruded flux so that good electrical contact with the jaws of the welding head can be maintained. This form of construction also allows a greater quantity of flux to be more firmly held to the core wire and assists in reducing splay at the arc.

Coilex has already been approved by a number of Classification Societies including Lloyd's Register of Shipping, The American Bureau of Shipping, the Ministry of Transport, and Det Norske Veritas, and other approval tests are at present in progress. The electrode is now in full scale production.

Murex Welding Processes, Ltd., Waltham Cross, Herts.

Back-Plunger Indicator

The back-plunger type of indicator has always been popular in numerous applications for which the more usual type of side plunger instrument is not so convenient. J. E. Baty and Co., Ltd., have recently introduced a complete range of back-plunger instruments. Hitherto, this type was available only in 0·001 in. and 0·01 mm., with choice of two graduations. The gauges have now been entirely re-designed and will be offered with a choice of readings in 0·001 in., 0·0005 in. (with two magnifications), 0·0001 in. and 0·01 mm. and a range of 14 graduations.



Normally, back-plunger indicators are supplied with a holding rod as shown in the illustration of the 0·0001 in. model, but the latest gauges are also provided with a $\frac{5}{16}$ in. diameter stem co-axial with the plunger, which is an alternative means of holding in inspection fixtures and the like. For this purpose, the holding rod may be removed.

J. E. Baty & Co., Ltd.

A.C. Vacuum Gauge

A new Alphatron vacuum gauge, operating on A.C. current, is now offered by Naresco Equipment Corporation, equipment sales subsidiary of National Research Corporation. The Model 517 Alphatron gauge has these features: (1) six ranges permitting the measurement of pressures from 1000 to 0·0001 mm. Hg. on a linear scale; (2) instantaneous response, for quick readings; (3) compact construction and light weight; and (4) a connection for a recorder.

Like other NRC Alphatron vacuum gauges, the Model 517 utilises a sealed radium source; this emits alpha particles and produces ionised gas molecules which are collected on a plate to produce a current indicating directly the measured pressure. The gauge cannot be damaged by exposure to atmospheric pressure, because the ion source operates at room temperature and at zero potential. Alphatron gauges are also claimed to be less susceptible to contamination than are hot element vacuum gauges.

Naresco Equipment Corporation, 160 *Charlemont St., Newton Highlands* 61, *Mass., U.S.A.*

S.I.G.M.A. Water-Cooled Gun

The Quasi-Arc Co., Ltd., are now sole licensees in this country for the S.I.G.M.A. welding process. This is an inert-gas-shielded consumable electrode process, for the welding of metals such as aluminium and stainless steel, employing a water-cooled gun shown in the illustration.

Water cooling allows the gun to be of very light, well balanced construction, which reduces operator fatigue to a minimum and facilitates welding in the vertical and overhead positions. The cooling water to the gun also cools the welding supply cable, permitting a great reduction in its size, and increased flexibility. With water cooling, a 50 amp. cable is used to carry welding currents up to 400 amp. and all leads to the gun are, therefore, light and flexible.

One trigger on the gun initiates the flow of water and argon shielding gas, and also operates the main welding contactor, thus simplifying welding operations.

The Quasi Arc Co., Ltd., Bilston, Staffs.

CURRENT LITERATURE

Book Notices

B.S.I. ANNUAL REPORT, 1953-54

200 pp. British Standards Institution, 2, Park Street, London, W.1. 5s. net.

For the first time since the war, the British Standards Institution has issued a full printed report on its activities in the many fields of industry and trade with which it is now concerned. The range of work undertaken by the Institution, as well as the growing interest in standards as a matter of both domestic and international concern, have indicated that a report of this kind should be published. Although it runs to a total of 200 pages, the Annual Report provides almost at a glance an impression of the very comprehensive range of industries which use B.S.I. facilities to prepare agreed standards for their products and services.

Reports on the standards projects undertaken and completed during the year under review by some sixty major industries occupy the largest single section of the book. They include a record of several thousands of items of " work in hand "—standards projects which are in various stages of development, from the initial idea to the preparation of new or revised drafts. This section above all gives a clear impression of the range and volume of B.S.I. activities and of the liveliness with which the work is kept constantly on the move. A separate special section records the total of well over 100 subjects in which international alignment of standards is being prepared through the International Organsation for Standardisation (I.S.O.) and the International Electrotechnical Commission (I.E.C.). Some 70 pages are devoted to lists of the members of the principal Councils and Industry Standards Committees working within the B.S.I.

The first section of the book deals with a variety of general subjects, ranging from the increased efficiency provided by the Institution's new premises at 2, Park Street, London, W.1, through research, modular co-ordination and Anglo-American terminology, to consumer goods, publicity and finance. A page of statistics indicates the continuing growth in B.S.I.'s activities on behalf of industry, together with greater efforts to publicise what is being done. The number of new and revised standards issued during the year to 31st March was 286, as compared with 260 in the preceding year, and copies of British Standards sold reached 914,000 as compared with 872,000. Of this total about a quarter are sold overseas. Subscribing members of the Institution now exceed 8,000, their contributions in the year totalling over £110,000. B.S.I. has 2,388 standing committees, on which 14,000 technicians and specialists from industry and the professions serve. The number of Committee Meetings held during the year was 3,470.

A.D.A. LIST OF PUBLICATIONS

This booklet gives details of the main series of technical books published by the Aluminium Development Association, 33, Grosvenor Street, London, W.1, viz. information bulletins, applications brochures, research reports and reprinted papers and articles; it also includes certain books dealing with the Association's membership, policy, organisation and services. There is also a note on *The Aluminium Courier*, an illustrated publication which seeks to interest both general readers and technical users (actual and potential) of aluminium and its alloys by surveying specific fields of application issue by issue, and giving brief descriptions of forming, finishing and other fabricating processes.

A.D.A. LIST OF FILMS, FILM STRIPS AND WALL CHARTS

The Aluminium Development Association's full service of visual aids includes films, charts, specimen boxes, handicraft notes, lantern slides, photographs. This publication contains a full description of the three major items, films, film strips and wall charts. At the date of publication 38 16-mm. sound films are available on loan to bona fide enquirers under certain conditions of operation. There are in addition 14 35-mm. film strips with many of which lecture notes are supplied, and three wall charts each accompanied by teachers' notes which have been designed also for students' private study.

BALANCES, WEIGHTS AND PRECISE LABORATORY WEIGHING

Notes on Applied Science, No. 7. 46 pp., illustrated. London, 1954. H.M. Stationery Office. 2s. net.

This paper-backed monograph is the seventh in a series of " Notes on Applied Science " published by the National Physical Laboratory with the object of providing for industrialists and technicians information on various scientific and technical subjects which is not readily available elsewhere. The present publication deals with the principles of the design, adjustment, use and testing of good quality knife-edge balances and weights for precise weighing in scientific laboratories. They are based largely on the experience and information gained by the N.P.L. in maintaining standards of mass and in testing weights and balances. The notes are written primarily to assist those concerned with precise weighing in industry and research, but they do not deal specifically with the specialised work of a national standards laboratory; and they do not provide all the information necessary for those who need to reach specially high accuracy in weighing. Such people will, however, find that in a number of respects the notes indicate the way to achieve this.

JUST THE JOB—A CAREER IN THE NON-FERROUS METAL INDUSTRY

The British Non-Ferrous Metals Federation has recently initiated the preparation of a new Operatives' Course in Non-Ferrous Metals of the City & Guilds of London Institute. The new course covers the history and background of the non-ferrous metals industry and deals in detail with all aspects of the plant and processes used in the manufacture and treatment of non-ferrous metals.

In order to publicise the course and attract young people to the industry, the Federation has prepared an illustrated booklet entitled " Just the Job—A Career in the Non-Ferrous Metal Industry," copies of which are available. This describes briefly the development of non-ferrous metals, their present importance in the life of the country and the development of new alloys and

uses which may be expected to take place in the future. It also stresses the advantages which the new course offers to those wishing to make a successful career in the industry.

Trade Publications

KEITH BLACKMAN, LTD., have recently issued new publications dealing with their products. No. 28 is a completely revised list dealing with the Tornado bifurcated range of fans, which is designed to handle obnoxious fumes, dust laden air or gases at normal or relatively high temperatures. The major advantage with this type of unit, which is now available in sizes ranging from 10 in. to 25 in. diameters, is that the fan casing is bifurcated or divided to accommodate the motor in complete isolation from the fumes or gases being handled. Publication No. 30 is another revised and improved catalogue relating to the Tornado range of high efficiency axial fans (Type AFX) which are V-rope driven by an externally mounted motor. Used for both industrial and marine applications, they are particularly suited to those conditions where the air or gas to be moved is contaminated with vapour, fumes, light dust or foreign matter such as paint pigment, textile fibres, etc. The size range is from 16 in. to 48 in. diameter; volume range from 1,000 to 40,000 cu. ft./min.; pressure range from 0·1 in. to 4 in. static water gauge.

IN the hacksaw blade brochure published by Darwins, Ltd., reference is made to the recent agreement between the British Hacksaw Makers' Association and the Hacksaw Manufacturers Association of America, Inc., which covers the standardisation of hacksaw blade sizes in Britain, Canada and the United States, and the main features of the new list are outlined. Guidance is given as to the application of the three grades of blade manufactured by Darwins: Toledo—high speed quality; Vanadia—regular tungsten quality; and Cobaltcrom—special abrasion-resisting quality. A more general, but no less valuable, part of the brochure contains instructions for effective sawing, and diagnoses of faults leading to particular troubles. Attention to such details can obviate the broken blades and stripped and worn teeth which are the inevitable consequences of abuse.

THE art of enamelling is of great antiquity and is probably of Western Asian origin. Pottery and bricks appear to have provided the basis for early enamelling operations in ancient Egypt, and there have been many changes in technique through the intervening centuries to the present day. The success of the operation depends on the basis material (now usually metal), the enamelling materials, and the procedure, and in a printed version of a paper read before the Northern Section of The Institute of Vitreous Enamellers, and issued by The Incandescent Heat Co., Ltd., the construction of enamelling furnaces is discussed in the light of the requirements of the process and of fuel economy. Numerous illustrations of typical installations are included.

FIRE cements form the subject of a revised and enlarged leaflet recently issued by J. H. Sankey & Son, Ltd., of Ilford. Three types of cement are detailed, Pyruma, Aluma and Siluma. Pyruma withstands intense and intermittent heat up to 1,580° C., and is supplied as cement mortar, patching cement, putty, fire concrete, wash, spraying grade, and stone cement. The Aluma plastic fire cement has been developed for bonding all firebricks with an alumina content of 40% and upwards. It withstands temperatures up to 1,800° C., and is recommended for use where conditions involving flame impingement, furnace dust, fluxes and molten metals are to be met. Siluma hot patching cement is specially prepared for the hot patching of fireclay, semi-silica and silica surfaces, as in gas retorts and coke oven walls.

THE commercial production of high purity aluminium, with its good ductility and malleability has led to its use in the building industry for such purposes as roofings, flashings and weatherings. In a recently issued wallet folder, British Aluminium Co., Ltd., has illustrated nine typical examples of the use of their Super Purity Aluminium for this purpose. They include houses, schools and churches, the earliest dating back to 1947.

A LEAFLET published by W. Canning & Co., Ltd., Birmingham, deals with the new Typhon plating barrel. The original model was so well received that the makers were encouraged to produce it in three sizes. The Typhon Minor (2860A) has an article capacity of 1 pint and the Typhon Major (2860B) a capacity of 4 pints, while the Typhon Master (2860C) can deal with 2–3 gallons of articles. All three models are suitable for the deposition of most metals other than chrome, and are particularly suitable for plating small components which cannot be treated in perforated barrels.

WE have received from Lincoln Electric Co., Ltd., Welwyn Garden City, No. 1 of a series of leaflets bearing the general title of "Origineering," which is defined as the science of originating new engineering designs. This first issue concerns the cutting of costs by careful planning, and by applying the economics of welded steel construction to whatever products are being made. After considering the basic material advantage of steel, attention is directed to the savings to be effected by the more efficient use of metal by putting the material in the right place, and by economical fabrication. Copies are available to readers in the management, design, creative and production fields.

Books Received

"Adhesive Bonding of Metals," By George Epstein. 218 pp., inc. index. New York and London, 1954. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 24s. net.

"Verhütten von Eisenerzen." By Professor Dr.-Ing. Dr. Mont. h.c. Robert Durrer. Second Edition. 159 pp., inc. 44 illustrations and name and subject indexes. Düsseldorf, 1954. Verlag Stahleisen M.B.H. Geb. DM. 18,50.

"Residual Stresses in Metals and Metal Construction." Edited by William R. Osgood. Prepared for the Ship Structure Committee under the direction of the Committee on Residual Stresses, National Academy of Sciences—National Research Council. 363 pp., inc. numerous illustrations and index. New York and London, 1954. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 80s. net.

"Rare Metals Handbook." Edited by Clifford A. Hampel. 657 pp., inc. index. New York and London, 1954. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 96s. net.

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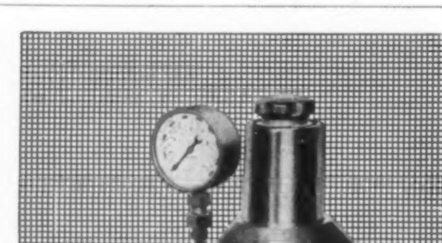

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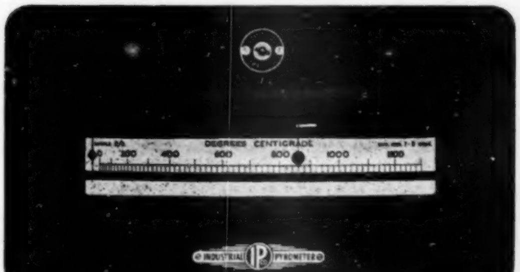

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NOVEMBER, 1954 Vol. L, No. 301

A Semi-Automatic Magnetic Crack Detector for Small Components

By J. W. Walley, Assoc.I.E.E., A.R.T.C.S.
Research Department, Metropolitan-Vickers Electrical Co., Ltd.

This paper describes a new form of magnetic crack detector which is designed to provide an easily operated unit for the rapid testing of small precision components with the minimum of handling. During one revolution of a handwheel, the component is subjected to both longitudinal and circumferential magnetisation, immersed in the magnetic fluid and inspected for surface cracks.

THE magnetic method of detecting cracks in ferrous metals is now well established in the engineering industry, and many forms of magnetic powder crack detection equipment are available. In the case of mass produced components it is usual to employ the crack detector only for magnetisation and immersion of the components in magnetic fluid, the examination for crack indications occurring later. This procedure naturally entails considerable handling of components wet with magnetic fluid, and it is during handling that the crack indications may be accidentally wiped off the component surface. Even with the most careful handling a serious crack may remain undetected due to wiping and cause a defective component to be accepted.

Small components are the most difficult of all to examine thoroughly without touching them at some point, and it is in these cases that there appears to be the greatest need for a machine which retains the component for examination. This requirement is provided for by the use of a novel holding arrangement embodied in a new crack detector.

Fundamental Principles

The process of magnetic crack detection can be conveniently sub-divided into three main stages which are as follows :—

Magnetisation.

Nearly all the magnetic methods of fault detection are based on the fact that the presence of a crack or flaw in a magnetised magnetic material causes a surface field distortion or flux ripple localised at the position of the fault. The distortion will be greatest when the magnetising field is so directed that it crosses the fault at right angles. It is also important to ensure that the strength of the magnetising field is sufficient to deal with the size and the material of the component. Hence the magnetic field must be correct in both direction and strength.

Detection.

For the detection of the field distortions that result from the presence of surface cracks, use is made of a magnetic fluid consisting of a thin oil in which fine particles of iron or a magnetic iron oxide are suspended.

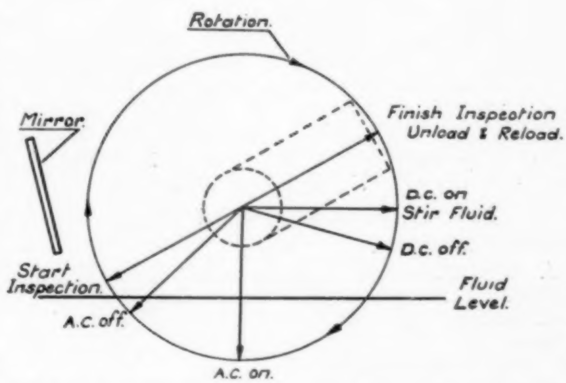

Fig. 1.—Circle diagram of semi-automatic magnetic crack detector.

When the fluid is applied to the surface of a magnetised component, particles in the vicinity of a surface crack are attracted by the local field distortion and form a ridge along the line of the crack, so indicating its presence.

Inspection.

The ridge of particles indicating a surface crack is about twenty times wider than the crack proper and, therefore, easily visible with the naked eye. Careful handling during inspection is most essential in order to avoid removing the particle formations before they come into view. A good colour contrast between the particle formation and the component surface is important. Black fluid shows up best on brightly machined surfaces, whilst for dark backgrounds either red or white fluid may be used.

Principle of Operation

The new machine utilises the principle of the single-throw crankshaft with the component under test occupying the position normally taken by the crank-pin. With such an arrangement the component can be revolved by means of a handwheel attached to the shaft whilst

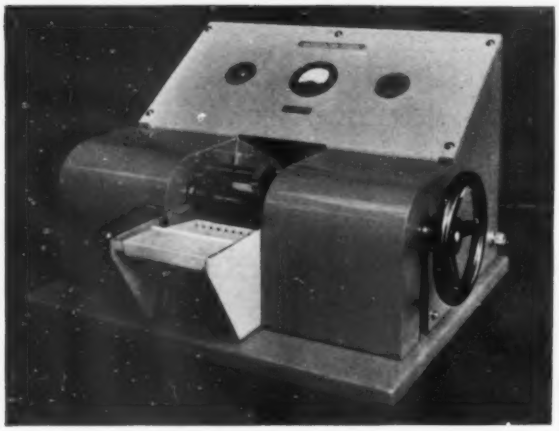

Fig. 2.—Semi-automatic magnetic crack detector testing an aero-engine gudgeon pin.

undergoing immersion, magnetisation and inspection. The sequence of operations is shown diagrammatically in Fig. 1. Since most of the moving parts of the machine can be isolated from the immersion bath; fouled joints and bearings due to magnetic particles are minimised.

Components are subjected to both longitudinal and circumferential magnetisation in order to detect surface cracks lying in any direction. The longitudinal magnetisation is obtained from D.C. magnetising coils and the circumferential magnetisation is effected by the passage of 50 c/s. A.C. directly through the component.

Description of the Crack Detector

General Arrangement.

A sheet aluminium cubicle is mounted on the rear portion of the base and houses the main and instrument transformers. The direct reading 0–600 amp. A.C. ammeter is mounted on the front panel alongside the D.C. indicator lamp and the D.C. fuse.

The front portion of the base carries a bedplate surmounted by two pedestal bearings. These support two cranks mounted face to face and rotatable in step on the same axis, the cranks being coupled by a non-magnetic shaft. This shaft is integral with the R.H. crank and slides axially inside the L.H. crank so that the latter may be positioned according to the length of of the component to be tested. The R.H. crank is spring-loaded in order to grip the component, the spring pressure being released by a face-cam at the loading and unloading point in the cycle.

The immersion bath is mounted at the centre of the bedplate below the cranks. On each side of the bath is a sheet aluminium shrouding to enclose the pedestal bearings, shafts, cams etc., and also the D.C. magnetising coils.

Fig. 2 is an oblique front view of the machine with a gudgeon pin clamped between the copper braid pads on the cranks, and Fig. 3 is the same view, but with the immersion bath and shroudings removed in order to service the machine.

Longitudinal Magnetisation.

This is a D.C. magnetisation which is applied along the length of the component in order to detect transverse flaws. Two magnetising coils are employed and mounted as near as possible to the component under test (see Fig. 3). The D.C. supply for the coils is obtained from a metal rectifier via a series signal lamp which is the D.C. indicator on the front panel. A cam-operated micro-switch is arranged to energise the coils as the component reaches the D.C. position as indicated in Fig. 1.

Since the component is part of an almost closed magnetic circuit comprising steel cranks, steel pedestal bearings and steel bedplate, the residual magnetisation after switch-off and immersion is adequate for surface crack detection. This arrangement reduces the free magnetic field from the submerged cranks which would otherwise filter out the particles from the magnetic fluid.

Circumferential Magnetisation.

A 50 c/s alternating current is passed directly through the component in order to provide a circumferential magnetisation which will detect longitudinal flaws. The current is obtained from a power transformer tapped at

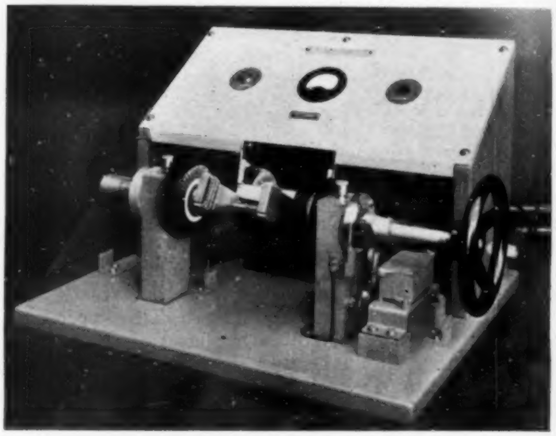

Fig. 3.—Semi-automatic magnetic crack detector prepared for servicing.

1, 2, 3 and 4 volts, so that the value may be adjusted to suit the diameter of the components being tested. No free field harmful to the magnetic fluid occurs during this operation.

Each pedestal bearing is insulated at the base from the bedplate, and the non-magnetic coupling shaft is also insulated from the R.H. crank. This ensures that all the heavy current passes into the component through the copper braid pads at the end of each crank. The spring-loading of the R.H. crank provides the end pressure required for good electrical contact, and the ⅛-in. copper braid pads increase the contact area and reduce localised heating.

Magnetic Fluid.

The magnetic fluid is contained in an immersion bath which is located between the pedestal bearings and beneath the cranks. Convection stirring is applied by means of a perforated paddle which is agitated by hand in order to maintain the particles in suspension. The low handle permits easy stirring and reduces the risk of contamination.

Capacity.

The L.H. crank can be adjusted to accommodate components from 0·5 in. up to 4·0 in. in length and having a maximum diameter of 1·5 in. Special testing

fixtures which may be required with irregularly shaped components can be based on the threaded holes provided.

Method of Use

Since the main function of the new machine is to facilitate mass production testing, it is envisaged that one setting will suffice for a large number of similar components. With the cranks in the loading position, the L.H. crank is released by a chuck key and adjusted axially until the component under test just passes between copper braid pads. The crank is then locked in position and the key removed.

A component is placed betwen the ends of the cranks and the handwheel turned slightly in a forward direction. This releases the spring which urges the cranks together and the component is clamped firmly in position. At the same time the D.C. magnetising coils are automatically switched on as indicated by the signal lamp. The lamp is also a reminder to the operator that the magnetic fluid must be stirred before continuing rotation of the handwheel which switches off the D.C. and immerses the component in the magnetic fluid. As the handwheel is turned forward again the alternating current is passed through the component and remains on until the component begins to emerge from the fluid. The component is allowed to drain for a few seconds whilst the detachable tray on the front of the bath is slid forward. At this point inspection for cracks begins and continues as the component is turned through 180° to the unloading position. To facilitate inspection a plane mirror is provided with which portions of the component remote from the operator can be viewed. In Fig. 4, transverse cracks on the far side of a gudgeon pin can be seen through the mirror which is mounted at the back of the bath.

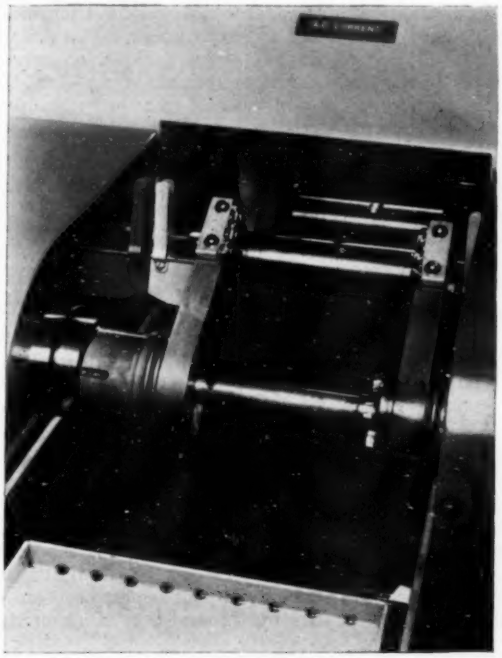

Fig. 4.—Transverse cracks on the far side of a gudgeon pin observed through the mirror.

TABLE I.—RELATION BETWEEN FIELD STRENGTH AND AIR-GAP.

Gap Setting (in.)	1	2	3	4
Field Strength (Oersteds)	950	500	330	280

TABLE II.—TRANSFORMER CURRENT FROM SECONDARY TAPPINGS.

Transformer Secondary Tapping (volt)	1	2	3	4
Component Current (amp.)	330	600	930	1230

The final movement of the handwheel opens the cranks and releases the component which drops into the tray. Then the component is lifted from the machine on the tray and tipped into the appropriate container, i.e., either accepted or rejected. A hole in the tray is provided to facilitate unloading.

The handwheel has moved through one complete revolution and the machine is ready to receive the next component.

Performance Tests

Several components known to contain cracks were tested in the machine and in each case the ease and rapidity of loading and unloading was particularly noticeable. The relation between the D.C. field strength and the air-gap between the cranks was determined with a direct-reading magnetometer and is shown in Table I.

With a 1 in. diameter by 3 in. long component in the machine, the longitudinal magnetising force on the surface was 75 Oersteds for the normal D.C. excitation current of 0·26 amp. On the A.C. side the same component was used to determine the current from the main transformer on each secondary tapping. See Table II.

The complete absence of burning at the copper braid pads demonstrated the efficiency of adequate end-pressure applied automatically by the machine. The effect of using a tray to collect and remove the wet components is that the operator has only to handle dry components when loading. This constitutes a marked improvement in the working conditions of the operator when compared with earlier machines.

When tests were made on a batch of taper rollers it was found that the average time for a complete test for each roller was of the order of 30 seconds. Allowing for improvement with experience this represents a throughput of about 1,000 components per 8 hour day per machine.

Future Development

The successful performance of the new crack detector shows that a design based on the method of holding a component between rotatable cranks has many advantages. Ease and speed of operation, convenience in loading, etc., are factors which are as important with a crack detector as with any other machine, especially in the drive for greater productivity. In the future, therefore, it is envisaged that larger machines will be developed along the same lines as the present machine. These will provide magnetic crack detectors capable of handling medium sized components more easily than existing immersion bath machines.

Another obvious development of the new machine is motorisation with push-button control. The rotary motion lends itself readily to conversion into an electric motor-driven machine with suitable reduction gears, so making it fully automatic.

Conclusions

A 100% magnetic inspection of small components on a mass production basis has now become a practical proposition. This is due to the introduction of an inspection stage into the testing procedure of a suitable magnetic crack detector in order to eliminate accidental removal of the crack indications.

From the operator's viewpoint, the automatic switching of the various circuits and the spring-maintained clamping arrangement will reduce operational fatigue. In addition, the machine can be operated in a sitting position and the amount of contact with the magnetic fluid will be reduced to a minimum.

The new machine has demonstrated once again the advantages of the end-pressure method of holding the component under test. This exposes the maximum surface area first to the action of the magnetic fluid and secondly to the view of the operator during inspection.

The principles of the magnetic crack detector described above can be usefully applied throughout the engineering industry in order to raise the standard of magnetic inspection above that attainable at present.

Acknowledgments

The author expresses thanks to Dr. Willis Jackson, F.R.S., Director of Research and Education, and to Mr. B. G. Churcher, M.Sc., M.I.E.E., Manager of Research Department, Metropolitan-Vickers Electrical Co., Ltd., for permission to publish this paper.

A Complexinetric Method for the Determination of Zinc in Aluminium Alloys

By J. C. Sergeant

Metallurgical Chemist, Department of Metallurgy, University of Birmingham.

A method is described for the determination of zinc in aluminium alloys in which a rapid sulphide separation technique precedes a titrimetric finish using di-sodium ethylene diamine tetra-acetic acid (E.D.T.A.) and Eriochrome Black as indicator.

AMONGST the most widely used aluminium alloys to-day are the members of the aluminium-zinc group which are used in the electrical, automobile, aircraft, toy and other industries. The zinc content varies from 2–4% in L.M.1 alloy, through 3–6% in common casting alloys, and 6–8% in D.T.D.687 sheet, to 9–13% in L.M.3 alloy. With such widespread application, it is not surprising that many laboratories concerned with the analysis of aluminium alloys handle large numbers of samples of the aluminium-zinc type.

Several methods are available for the estimation of zinc[1-5] since this metal may be determined gravimetrically, titrimetrically, electrolytically, polarographically, etc. Zinc passes into solution, however, with all the standard methods for opening out aluminium alloys, so that at some stage in the procedure the zinc has to be isolated by a sulphide separation: one of the exceptions to this general rule is Norwitz's electrolytic method, although in this case the final deposit comprises the iron and copper as well as the zinc. Using any of these methods, really speedy analysis is not possible, and the author felt that for routine work a rapid method would be of considerable value.

The aim was to evolve a method which would be sufficiently accurate for routine analytical purposes, speedy, and yet easy to operate. First attempts involved the use of a method of complexing or masking interfering elements, so as to reach the titration stage without filtering, or at the worst with only one filtration. Unfortunately, the fact that the more common alloys and scrap metal often contain appreciable amounts of iron and manganese, whose masking would upset the titration, rendered this scheme impracticable. Another possibility, opening out the alloy with caustic soda, when the bulk of the zinc passes into solution with the aluminium and silicon, is likewise unsuitable because an appreciable amount of zinc remains with the insoluble residue containing the interfering elements. It became evident, therefore, that a zinc separation would be necessary, and as it had already been decided that the sulphide separation from formic or acetic acid media was too lengthy, an organic sulphide reagent was sought.

The most likely reagent appeared to be trithiocarbonic acid,[6, 7] which rapidly separated the zinc from a sulphuric acid solution, and did not appear to require very accurate control of the pH value. Unfortunately, at the time of writing, the reagent is virtually unobtainable in this country. The sodium salt may be made in the laboratory, but not without difficulty, and even then its stability cannot be guaranteed. It was decided, therefore, that a cheap and easily obtainable reagent would be preferable.

After many test precipitations had been made, it was found that, when a sodium carbonate/sodium sulphide solution was added to a dilute nitric acid solution containing zinc, the element was rapidly precipitated at pH 4·5–7·0, and that the precipitate was flocculent, settled quickly and could easily be filtered on a pulp pad. The last feature was important in itself, as the filtration of zinc sulphide had always been a slow and tedious operation. This problem having been solved, work proceeded on the method as a whole. Copper and nickel were also precipitated, but Flaschka[8] had already established that when copper, nickel and zinc are complexed with potassium cyanide, the cyanide of zinc is less stable than the cyanides of the other two metals and can be decomposed by the addition of formaldehyde, thus allowing the zinc to be titrated. Some iron and aluminium may also be carried over during the zinc separation, but can be removed quite easily by the addition of ammonia.

Procedure

In the method chosen, the alloy is attacked with a mixture of nitric and hydrochloric acids, the solution

diluted with water, and tartaric acid added to hold up the precipitation of aluminium, iron, etc. The solution is then adjusted to the correct degree of acidity with dilute nitric acid, and a predetermined amount of sodium carbonate/sodium sulphide solution added to neutralise the acidity and precipitate the zinc, along with the copper, nickel, etc. The solution is then brought to the boil, allowed to stand for a short while, and filtered on a pulp pad. Washing is carried out with dilute sodium carbonate/sodium sulphide solution: the pad is then treated with hot dilute hydrochloric acid and washed through with small amounts of hot water. The filtrate is transferred to the original beaker, ammonium chloride and bromine water added, and the solution brought to a boil to oxidise the sulphur. The solution is then made slightly ammoniacal to remove iron, aluminium, etc., which have been carried through. These precipitates are filtered on a pulp pad, washed with ammonium chloride solution, and the filtrate transferred to a titration beaker. A further small addition of ammonia is made, any remaining copper and nickel complexed with potassium cyanide solution, and the zinc decomposed by formaldyhyde. The sample is now ready for titration with di-sodium ethylene diamine tetra-acetic acid (E.D.T.A.), using Eriochrome Black as indicator.

Reagents

(1) *Hydrochloric Acid.*—Concentrated A.R. quality reagent.

(2) *Nitric Acid.*—Concentrated A.R. quality reagent.

(3) *Tartaric Acid.*—Solid A.R. quality reagent.

(4) *Methyl Red Indicator.*—Dissolve 0·1 g. reagent in 60 ml. alcohol and make up to 100 ml. with water.

(5) *Ammonia Solution.*—S.G. 0·880.

(6) *Nitric Acid (Dilute).*—10% v/v A.R. quality reagent in water.

(7) *Sodium Carbonate/Sodium Sulphide Solution.*—dissolve 50 g. sodium carbonate (A.R. quality) in hot water, followed by 100 g. sodium sulphide (A.R. quality), and dilute to 1 litre with water.

(8) *Sodium Carbonate/Sodium Sulphide Wash.*—Make up as required by adding 2 ml. Reagent 7 to 100 ml. cold distilled water.

(9) *Hydrochloric Acid (Dilute).*—50% v/v A.R. quality reagent in water.

(10) *Ammonium Chloride.*—Solid A.R. quality reagent.

(11) *Bromine Water.*—Saturated solution.

(12) *Ammonium Chloride Wash.*—Dissolve 1–2 g. solid A.R. quality reagent in 100 ml. water, as required.

(13) *Potassium Cyanide Solution.*—20% w/v A.R. quality reagent in water.

(14) *Formaldehyde Solution.*—50% v/v of 40% solution in water.

(15) *E.D.T.A. Solution (N/20).*—Dissolve 9·5 g. reagent in water and make up to 1 litre.

(16) *Eriochrome Black Solution.*—Dissolve 0·5 g. reagent and 3 g. hydroxylamine hydrochloride in 100 ml. alcohol and filter.

(17) *Distilled Water.*—Used throughout the method.

Method

Cautiously add to the sample, a few drops at a time, 5 ml. concentrated hydrochloric acid for every 0·5 g. of sample,* followed by an equal amount of concentrated nitric acid. When the violent reaction has subsided, wash down the cover glass and the side of the beaker with a small amount of warm water, place the beaker on the hot plate and bring to the boil for 1–2 minutes. Remove from the hot plate and dilute to 50–60 ml. with cold water, add 3 g. tartaric acid per 0·5 g. of sample, and neutralise the acid with ammonia solution, using methyl red as indicator. Re-acidify the solution with 10 ml. dilute nitric acid (10%), add sufficient sodium carbonate/sodium sulphide solution to neutralise the nitric acid (predetermined—approximately 15 ml.†), and check the *p*H value with test paper, adjusting if necessary to 5–7. Replace the beaker on the hot plate, add a pinch of filter pulp, bring to the boil and allow to stand for 1–2 minutes on the edge of the plate. Filter the combined precipitates of zinc, copper, nickel, etc., through a pulp pad, and wash 4–5 times using the dilute carbonate/sulphide wash from a polythene wash-bottle. Treat the pad with 15 ml. hot dilute hydrochloric acid (50%) to dissolve the zinc, followed by 4 small washes with hot water.

Transfer the filtrate to the original beaker, add 2–3 g. ammonium chloride and sufficient bromine water to colour the solution, bring to the boil to oxidise sulphur, and make just ammoniacal to precipitate the iron and aluminium carried through during the zinc separation. Add a pinch of filter pulp and bring the solution back to the boil. Filter through a pulp pad, giving 4 small washes with the ammonium chloride solution.

Transfer the solution to the titration beaker, add 5 ml. ammonia solution, 4 ml. potassium cyanide solution, and 9–11 drops of Eriochrome Black indicator. If the solution turns blue, add 10 ml. formaldehyde solution and titrate with the standard E.D.T.A. solution to a light blue or greenish end-point.

If, however, the solution is red before the addition of formaldehyde, some interfering element such as lead may be present, in which case the following procedure should be followed. Add a further 2 ml. potassium cyanide solution and mix thoroughly; then very cautiously discharge the red colour to a blue end-point by adding E.D.T.A. solution dropwise from a burette. Finally, add 12 ml. formaldehyde solution, mix well to decompose the zinc, and titrate to the blue or greenish end-point with E.D.T.A. solution, making a further addition of 2–3 ml. formaldehyde, to ensure that all the zinc has been decomposed and titrated.

1 ml. N/20 E.D.T.A. solution = approx. 0·00169 g. zinc.

Notes

(1) The sample is weighed into 400-ml. tall form beakers.

(2) The method is designed for the analysis of aluminium-zinc alloys, but it may be used for the determination of zinc as an impurity if high silicon is filtered off prior to the precipitation of the zinc.

(3) The following table of quantities of sample and reagents should be adhered to:—

Estimated Zinc %	Sample (g.)	Volume of Hydrochloric Acid (ml.)	Volume of Nitric Acid (ml.)	Weight of Tartaric Acid (g.)
<1	2	20	20	12
1–2	1	10	10	6
2–7	0·5	5	5	3
7–14	0·25	5	5	2

* See note 3.

† See note 4.

For zinc contents above 14%, N/10 E.D.T.A. should be used.

(4) To predetermine the balance of the dilute nitric acid (10%) to the sodium carbonate/sodium sulphide solution, add 10 ml. of the acid to approximately 100 ml. water and colour with methyl red. Measure out 20 ml. sodium carbonate/sodium sulphide solution into a 25 ml. measuring cylinder, and add to the acid solution slowly, until the red colour is just discharged. Record the total required.

(5) During washing of the zinc precipitate, the filtrate is liable to become turbid. This is probably due to colloidal dispersion and unstable iron which is washed from the zinc/copper precipitate. It may, however, be ignored, as the zinc complex is quite insoluble.

(6) Impurities normally found in aluminium alloys do not interfere with the method.

(7) A suction pump is essential for all filtrations.

(8) It is recommended that all titrations should be carried out in a 450-ml. conical beaker.

(9) For normal work a 25-ml. burette is used, but for very small amounts a 5-ml. micro-burette is recommended.

(10) The author uses a 2 ml. tilt action pipette for measuring potassium cyanide solution.

(11) To standardise N/20 E.D.T.A. solution, take approx. 0·2 g. of pure zinc metal, record the exact weight, dissolve in a little dilute nitric acid and make up to 100 ml. Pipette out 10 ml. aliquots into titration beakers, dilute to 50–60 ml. with water, add 2–3 g. ammonium chloride and 4 ml. ammonia solution and titrate in the usual way.

TABLE I.—TYPICAL RESULTS

Sample Used	Zn %	
	Present	Found
D.T.D.424	0·80	0·81
"	0·46	0·46
L.33	0·12	0·11
D.T.D.428	1·08	1·10
"	2·08	2·06 2·10
"	3·00	2·97 3·04 3·03
L.M.3	9·25	9·19 9·23 9·29

(12) When making up Eriochrome Black indicator, no heat should be applied to the solution, as this impairs the sharpness of the end-point. The reagents should stand, with occasional stirring, in the alcohol for 10–15 minutes. The solution should then be filtered.

(13) An experienced operator should complete one determination in 20–25 minutes.

Results

Typical results obtained by using this method on a range of aluminium alloys are presented in Table I.

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Institution of Metallurgists

Examination Results

The following candidates have been successful in the 1954 Examinations of the Institution of Metallurgists.

Fellowship: N. F. Sheppard.

Associateship: D. R. Andrews, B. Bancroft, D. L. Biggs, N. T. Burgess, A. H. Burn, W. E. Challis, C. Dawes, W. G. J. Eley, G. J. Evans, F. W. Fahy, G. B. Fletcher, G. N. Flint, J. H. Gardiner, W. W. Glick, R. F. Hills, G. F. T. Jay, R. A. Kirkham, P. A. Lovett, W. F. Lycett, S. M. McConnell, N. A. MacQuarrie, R. Marshall, J. C. Moore, W. G. Murray, M. G. Neu, K. A. Reynolds, B. F. Sharpe, J. F. Sillitoe, J. E. Stolarczyk, R. T. Sumerling, M. G. Wang, A. G. Ward, D. E. Wetherly, M. E. Wilkie, G. A. Wood, R. W. A. Wright.

Licentiateship: J. R. Adair, M. Atkinson, G. T. Barlow, K. W. Bee, H. T. Bidwell, G. Bromfield, G. H. Broomfield, P. G. Browett, P. J. Burdon, J. F. Cleave, D. F. Clarke, B. W. Cordob, G. J. Cox, G. Davies, R. F. Davies, M. Dickson, H. Drew, N. T. Dukes, M. J. Evans, H. O. Fletcher, R. S. Godwin, B. G. Goodyer, G. A. W. Green, I. H. Green, J. M. Greenhill, D. M. Grounds, R. Hall, R. Holmes, R. W. Hugill, R. Horsley, G. J. T. Hume, M. F. Hurst, J. Jarvis, K. B. Johnston, L. P. Judson, P. W. Leach, J. Lee, B. A. Lloyd, R. C. Lycett, T. J. McDonald, D. J. Mabbutt, G. A. Mowbray, J. M. Muir, G. Nicholas, R. I. Parker, A. C. Pleass, J. A. Rawlins, W. A. B. Ritchie, G. Sale, B. C. Scogings, N. Scrimgeour, H. S. Smith, J. B. Stebbings, D. C. Stock, G. Strickland-Clark, C. A. Stubbington, G. B. Stubbs, LeR. R. Sumner, B. Sweeney, H. Sykes, Z. C. Szkopiak, J. Taylor, J. D. Taylor, L. F. Taylor, P. A. Tomblin, N. Tommis, G. M. L. Tuchmann, P. Wagstaff, P. D. Webster, R. C. Williamson, W. W. Wilson, P. G. Woodhouse, D. A. Whyte, P. G. Partridge, K. G. Rao.

Visit to Instrument Works

Fifteen students and tutorial staff connected with the B.C.I.A. Supplementary Scholarship Scheme at Brooklands County Technical College, Weybridge, visited the works of George Kent, Ltd., at Luton, on Wednesday, 13th October. Following a tour of the works taking in the departments concerned with training, instrument assembly, instrument calibration, general machinery, general engineering, panels, customer training, casting production, mechanical meters, and meter testing, the visitors attended a lecture on the use of instruments in the coking industry.

B.W.R.A. Open Days

The Metallurgical Laboratories of the British Welding Research Association are holding "Open Days" on Tuesday, 23rd and Wednesday, 24th November, 1954, at 29, Park Crescent, London, W.1. Researches on both ferrous and non-ferrous alloys willl be displayed covering many welding processes including the argon-arc, metal arc and self-adjusting arc processes. Admission will be by ticket only and persons who wish to attend should write to the Secretary, British Welding Research Association, 29, Park Crescent, London, W.1.